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Human Exploration of Mars: Preliminary Lists of Crew Tasks

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"The human factor is three quarters of any expedition."
— Roald Amundsen

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The cover illustration, titled, Exploring Mars, is from the BBC/Impossible Films, Ltd., production, *Space Odyssey: Voyage to the Planets*, which was broadcast in two parts in November 2004. The "fictional documentary" was written and directed by Joe Ahearne and produced by Christopher Riley, who received the 2005 Sir Arthur Clarke Award for Best TV & Radio Presentation.
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EXECUTIVE SUMMARY

This preliminary report provides lists of tasks that were developed during a three-year study conducted under Cooperative Agreement NNX15AW34G/NNX16AQ86G for the Human Factors and Behavioral Performance Element, Human Performance Program, located at the National Aeronautics and Space Administration's (NASA) Johnson Space Center. The tasks were identified during interviews and archival research as likely to be performed during the first few human expeditions to Mars. The tasks are consistent with Design Reference Architecture-5, NASA's most-recent published plan for the human exploration of Mars.

The 1,125 tasks listed in this document are organized by 12 mission phases and represent preliminary estimates of what tasks are likely required from launch to landing 30 months later. Also included in the lists are tasks for which crew members must be prepared, but would only be performed in emergencies. By focusing on an expedition to Mars, we have considered the extremes of what is possible for human space exploration during the first half of the 21st Century and accommodated the human requirements for missions to asteroids and a return to the Moon.

The study under which the task lists were developed addresses the Risk of Inadequate Mission, Process, and Task Design and the Risk of Performance Errors Due to Training Deficiencies during exploration-class space missions by identifying and analyzing the tasks that will be conducted by human crew during an expedition to Mars and the abilities, skills, and knowledge that will be required of crew members.

The current research is ongoing and will conclude with a final report that documents all research activities and presents the results of task and ability analyses and the implications of study results to crew size and composition, personnel selection and training, and design of equipment and procedures. *This interim report has been prepared to facilitate dissemination of the task lists to others whose research might benefit from detailed information about the work and other activities that are likely to be performed during initial human expeditions to Mars.*

Credit: NASA/JPL

First Photo Taken on Mars, Viking 1, 20 July 1976.

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INTRODUCTION

This is a preliminary report of ongoing research that has identified 1,125 tasks that are likely to be performed during initial human expeditions to Mars. The purpose of the report is to facilitate immediate access to the task inventory by researchers whose efforts might benefit from concrete examples of the work that will likely be performed by the first human explorers of Mars and the tasks for which crew members must be prepared to perform in response to emergencies. The research that led to the task lists is being conducted under Cooperative Agreement NNX15AW34G / NNX16AQ86G for the Human Factors and Behavioral Performance Element, Human Performance Program, NASA's Johnson Space Center. The study is ongoing and will conclude with a final report that documents all research activities and presents the results of task and ability analyses and the implications of study results to crew size and composition, personnel selection and training, and design of equipment and procedures. The research addresses the Risk of Inadequate Mission, Process, and Task Design and the Risk of Performance Errors Due to Training Deficiencies by identifying the work that will be performed during an expedition to Mars and the abilities, skills, and knowledge that will be required of crew members. The study began by developing the comprehensive inventory of 1,125 tasks that are likely to be performed during the 12 phases of initial human expeditions to Mars, from launch to landing 30 months later. This full-mission task inventory was generated by a comprehensive review of documentation and concepts of operations with the understanding that plans and tasks might change in response to continuing technological development. *Note: This interim report includes no discussion of analyses and has been prepared solely to facilitate dissemination of the task lists to others whose research might benefit from detailed information about the work and other activities that are likely to be performed during the human exploration of Mars.*

DEVELOPING THE TASK LISTS

Human factors specialists usually rely on job descriptions, training documents, written procedures, decision aids, and interviews with job incumbents for information that can be used to develop task statements for analysis. These sources are essential when developing task lists for existing equipment, systems, or processes. Identifying tasks for a new or proposed system requires the analyst to review specification documents, incorporate evidence from simulated operations with mock-ups, and/or perform hands-on operations using prototypes of the system. In contrast to the usual task analysis, rather than focusing on a "system," the focus of the current research is a 30-month expedition. Also, no actual equipment has been developed and there are few references in published material to the tasks that might be performed during the expedition. These factors required the research team to review a wide range of material concerning the human exploration of Mars and to infer tasks by extrapolating from published and unpublished sources and from analogous jobs and systems. The Appendix presents the published sources used during development of the task lists.

We reviewed a broad range of documents relevant to the human exploration of Mars, beginning with von Braun's *Mars Project* and the series of *Colliers* magazine articles that introduced the possibility of Mars exploration to the general public. We then reviewed Mars expedition planning documents, in chronological order of publication, beginning with a study by researchers at the Lewis Research Center that began in 1957, only one month after Sputnik 1 and a full year before the National Advisory Committee on Aeronautics (NACA) laboratory became part of the new organization, NASA.[1] Our review progressed through the decades and concluded

[1] Lewis was renamed Glenn Research Center at Lewis Field in 1999.

with NASA's most recent plan for the human exploration of Mars, Design Reference Architecture-5, published in 2009.[2]

Our archival research was supplemented by interviews with Subject Matter Experts (SMEs) about likely biological, geological, and maintenance tasks. Internal procedural descriptions of expected medical conditions and teleoperations led to the development of medical and robotic tasks. The research team met weekly via teleconference to identify gaps in the task lists and to perform preliminary analyses.

We divided the mission profile into the 12 phases described by Brian O'Leary to help organize the growing inventory of task statements; slight changes were required to adapt O'Leary's assumption of an Earth Orbit Rendezvous (EOR) after the Transit to Earth to be consistent with the Direct Descent method specified in DRA-5.[3] The DRA-5 plan, which provided the basis for our assumptions, is summarized, below.

THE 12 PHASES OF A HUMAN EXPEDITION TO MARS

Launch to Low-Earth Orbit or Cis-Lunar Orbit

The first phase of the mission begins with the crew entering the Earth Ascent Vehicle (EAV) on the launch pad and ends with the EAV docking with the interplanetary space craft in either Low-Earth Orbit (LEO) or at a Lagrange point near the Moon (i.e., Cis-Lunar, or CLO). The phase would be similar to a journey to the International Space Station (ISS) if the destination were in LEO (24 to 48 hours) and longer if the interplanetary space craft were to be waiting in CLO (75 hours). The duration is assumed to be 84 hours (which is slightly longer than the time required for Apollo 11 to reach the Moon) for this mission phase.

Pre-Trans Mars Injection and Trans Mars Injection

The second phase of the mission begins with the Mars crew entering the interplanetary space craft where they will be greeted by a team of astronauts who have prepared the ship for the journey to Mars and who will return to Earth in either the EAV or a similar space vehicle. This phase ends when the engines are shut down after the burn to achieve the correct course for the cruise to Mars. This phase is assumed to last four days, which will include final preparations and culminate with the main engine burn of approximately 60 minutes.

Cruise to Mars

The third phase of the mission is the unpowered cruise to Mars, which will take approximately 180 days (i.e., six months). The crew will be busy during this phase exercising and performing training tasks using configurable simulators; some refresher training will be performed, but most of the training will be new (in response to a strategy to transfer much of the pre-launch training burden to the cruise phase).

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[2] Bret Drake (Editor). *Human Exploration of Mars Design Reference Architecture 5.0*. NASA/SP–2009–566. Washington, DC: NASA Headquarters (July) 2009. http://www.nasa.gov/pdf/373665main_NASA-SP-2009-566.pdf Bret Drake (Editor). *Human Exploration of Mars Design Reference Architecture 5.0 Addendum*. NASA/SP–2009–566-ADD. Washington, DC: NASA Headquarters (July) 2009. http://www.nasa.gov/pdf/373667main_NASA-SP-2009-566-ADD.pdf

[3] Brian O'Leary. *Mars 1999: Exclusive Preview of the US-Soviet Manned Mission*. Harrisburg, PA: Stackpole Books, 1987.

Mars Orbit Injection

The fourth phase of the mission assumes six days of intermittent preparation as the interplanetary space craft approaches Mars and the crew makes final course corrections. This phase ends with 12 hours of high-tempo activity preceding a 60-minute main engine burn to slow the ship, which will be pointed in the opposite direction of travel.

Mars Orbit

The fifth phase of the mission begins as the interplanetary ship approaches and then docks with a pre-positioned Mars Descent Vehicle (MDV), which is located in an elliptical orbit with a 1-Sol (one Martian day) period; the orbit places the space craft over the landing site once per Martian day at the same time of day. The rendezvous and docking are assumed to take approximately 48 hours and another 48 hours for the crew to enter the Mars Descent Vehicle (MDV), configure systems, perform final checks, and communicate with Earth in preparation for descent to the surface of Mars.

Mars Surface Descent

The sixth phase of the mission begins with the crew securing themselves in the Mars Descent Vehicle (MDV) where they will perform final checks before undocking from the interplanetary space craft and then initiating the deorbit burn at the highest point of the parking orbit (apoapsis). The MDV will descend through half of the parking orbit (about 12 hours) at the end of which is atmospheric entry and the 10 to 20-minute terminal descent burn. Approximately 14 hours are assumed from ingress in Mars orbit to egress of the MDV following landing, shutdown of MDV systems, and initial communications from the planetary surface.

Mars Surface Operations

The seventh and longest phase of the mission begins with the crew walking from the Mars Descent Vehicle (MDV) to the pre-positioned Mars Habitat following landing and ends approximately 545 days later when the crew enters the pre-positioned Mars Ascent Vehicle (MAV) to return to Mars orbit and the interplanetary ship. Crew time on the planetary surface will be spent performing construction and maintenance; housekeeping and planning; geological and biological science in the vicinity of the habitat and during mechanized traverses; and communicating among the members of the crew and with Earth (communications response lags with Earth will be approximately 20 minutes).

Mars Surface Ascent

The eighth phase of the mission begins when the crew enters the Mars Ascent Vehicle (MAV) to prepare for launching from the surface of Mars to rendezvous with the interplanetary ship in Mars orbit. Approximately 14 hours are assumed from ingress to the MAV and shutdown of MAV systems after docking with the interplanetary ship in Mars orbit. A “missed attempt” for rendezvous would add 24 hours to the duration of this mission phase.

Trans-Earth Injection

The ninth phase of the mission begins with the crew preparing the interplanetary ship for the journey home and ends approximately six days later after a main engine burn of 60 minutes has propelled the ship on a course to intercept Earth.

Cruise to Earth

The tenth phase of the mission is the unpowered cruise to Earth, which will take approximately 180 days (i.e., six months). The crew will perform refresher training using onboard com-

puter simulations to prepare for the final phases of the mission; however, most of the crew's time will be devoted to exercise and to science tasks to provide meaningful work during the cruise.

Earth Approach

The eleventh phase of the mission begins approximately five days before landing with the crew transferring from the interplanetary ship into an attached Orion-type Earth Descent Vehicle (EDV) and undocking. The interplanetary spacecraft continues on it course unoccupied indefinitely while the crew makes final course corrections in cramped conditions onboard the EDV during the five-day approach to Earth.

Earth Surface Descent

The final phase of the mission begins with atmospheric entry, which will involve substantial g-loading and be similar to the "skip" trajectories of Apollo capsule landings. Precision will be required to avoid either intolerable atmospheric friction or skipping off the atmosphere. The duration from first atmospheric interface to landing under parachutes will be 20 to 30 minutes.

COMPOSING TASK STATEMENTS

The primary objective of the current study is to develop a comprehensive understanding of the human requirements for space exploration in order to identify the specific and generalizable skills necessary to perform the work under operational conditions. For this reason, it was necessary to include descriptions of all tasks performed by each specialty represented by members of the Mars expedition crew. The Mars mission plans that were reviewed during the current study specified crew sizes ranging from two to 70, with six or eight considered by modern planners to be ideal to accomplish all mission objectives and to return to Earth safely. Most of the mission plans also assumed the crew roles to be Commander, Pilot, Medical Officer, Scientist (geologist, biologist), and Engineer (mechanical, electrical, nuclear). Among our goals has been to provide data-driven recommendations for the number of crew members and for their specialties. That is, no assumptions about crew roles were made during the study, rather, the results of the task analysis will lead directly to those recommendations. These recommendations will be presented in the future final report for this study.

Each task identified during the research was phrased to begin with an action verb, followed by the object of the sentence, and then a description of how and under what conditions the task would be performed; task statements concluded with the reason for the action, in most cases. For example: *Enter control inputs, manually with gloved fingers, to override automatic firing of retro rockets for Mars Surface Descent maneuver if automated system fails.*

The goal for this task analysis is to identify and record four specific elements of each task:

1) What is done? 2) To what is it done? 3) How is it done? 4) Why is it done?

Inspect circuit board, visually, to detect scorching or other evidence of electrical short.

Pound seismometers into rock, manually using slide hammer while wearing surface EVA suit, to deploy sensors.

View ultra-sonic display, visually while manipulating hand-held device manually, to interpret results of ultra-sonic imaging test.

We reviewed the task lists in an iterative process to ensure that task statements were phrased systematically, which would maximize comparability during subsequent data-collection and analysis, and also remove variable syntax as a possible source of experimental bias. The resulting lists of formatted task statements together provide our best estimates of the work that will be performed by members of the crew during an expedition to Mars, and the tasks for which they must be prepared to perform during emergencies.

The preliminary lists for the 12 Mars Expedition phases contained a total of 1,125 tasks, as illustrated in the table, below. Mars Surface Operations (MSO) has the largest number of tasks, which would be performed during the 18-months the crew remains on the planetary surface. MSO is followed by the Cruise to Mars and Cruise to Earth phases in numbers of tasks, which would be performed during the six-month transits to and from Mars. Many of the tasks are the same in the two cruise phases, but conditions will be different (i.e., before and after spending approximately 540 days on Mars); they are counted twice for this reason. Also, many of the tasks would only be performed in the event of equipment or software malfunction, or in response to medical emergencies.

Mission Phase	Tasks	Mission Phase	Tasks
Launch to LEO/CLO	60	Mars Surface Operations	484
Trans-Mars Injection	19	Mars Surface Ascent	29
Cruise to Mars	206	Trans-Earth Injection	10
Mars Orbit Injection	10	Cruise to Earth	204
Mars Orbit	13	Earth Approach	26
Mars Surface Descent	29	Earth Surface Descent	35
		Total	1,125

We asked a highly-experienced mission planner, a scientist astronaut, and a high-ranking NASA scientist-manager to review and then comment on our Mars expedition task lists. The mission planner responded that the lists were comprehensive and recommended a few minor changes to MSO tasks based on the latest, unpublished mission plans (e.g., length of ladder, method for hoisting loads). The scientist manager responded that the lists were comprehensive and looked like "behind the scenes at *The Martian*," referring to the 2015 feature film that portrayed a human expedition to Mars. The astronaut scientist responded that the lists were comprehensive, but there were too many task statements for SMEs to rate each one during the planned data-collection effort. The research team was encouraged by the experts' review of our lists, but we were concerned about the astronaut's comment. Based on our internal testing and feedback from the experts, we estimated that it would take between four and five hours to rate all 1,125 tasks, which, of course is too long to expect volunteers to devote to our study.

In response to the astronaut's feedback, the research team decided to categorize the tasks within each mission phase according to similarity and then compose a statement that summarized the constituent tasks. This process resulted in a total of 158 summary task statements (representing the 1,125 tasks); for example, the 484 Mars Surface Operations tasks were reduced to 55 summary task statements and the 206 Cruise to Mars tasks were reduced to 27 summary statements. A summary statement and the corresponding EVA tasks from the MSO phase are reproduced, below.

Example of a Summary Task Statement and Constituent Tasks from the Master List

Perform surface EVA physical functions on foot during Mars Surface Operations.	
	Carry incapacitated crew mate 20 meters to surface rover, manually while both are wearing surface EVA suits, to prepare for medical treatment.
	Rise from prone position, using arms and legs while wearing surface EVA suit, to recover from fall on flat surface.
	Rise from prone position, using arms and legs while wearing surface EVA suit, to recover from fall in loose regolith.
	Bend over/stoop while wearing surface EVA suit to retrieve hand tool from planet surface.
	Climb 3 meter ladder, manually while wearing surface EVA suit, to access Mars Surface Ascent Vehicle.
	Adjust surface EVA suit controls, manually with gloved fingers, to operate mobile communications with Mars habitat personnel.
	Adjust surface EVA suit controls, manually with gloved fingers, to optimize mobile life support system.
	Carry harvested plant material from greenhouse to surface habitat galley, manually while wearing EVA suit, to prepare for crew consumption.

Credit: Twentieth Century Fox Film Corporation

Dig loose regolith from around surface rover wheel, manually using shovel while wearing surface EVA suit, to regain traction to proceed, a task performed by Mark Watney (Matt Damon) in *The Martian* (2015).

ASSUMPTIONS CONCERNING MARS EXPEDITION TASKS

Assumptions about the mission profile that guided development of the Mars Expedition task lists are summarized, below; the assumptions are consistent with DRA-5, but include elements derived from other sources, such as our discussions with SMEs. The complete inventory of tasks is presented in the following pages, organized by the 12, sequential mission phases (titled in red) and summary task statements (in bold). Durations and summaries of crew activities introduce each of the 12 lists.

ASSUMPTIONS ABOUT THE MISSION PROFILE

A Conjunction Class (approximately 500-day surface stay) mission profile is assumed with an out-bound Earth Orbit and Mars Orbit Rendezvous (MOR); Earth Orbit Rendezvous in Low-Earth Orbit (LEO) or Cis-Lunar Orbit (CLO) are accommodated by this task inventory. A six-month transit, or cruise, to Mars is followed by all crew members descending to the surface of Mars from the (interplanetary) space craft in a Mars Excursion Vehicle (MEV)/Mars Descent Vehicle (MDV); the (interplanetary) space craft remains untended in Mars Orbit. Pre-positioned on the surface are habitats, laboratories, sample storage facilities, and greenhouses (some of which require inflation and siting by the human crew); a nuclear-powered electricity-generating plant; teleoperated robot rovers (TROVs), at least two pressurized surface rovers, excavation and drilling equipment/vehicles; automatically-operating machinery for extracting O_2 and fuel from Martian atmosphere and subsurface H_2O, and tanks for storing the material produced; also pre-positioned is at least one Mars Ascent Vehicle (MAV) for returning the crew to the space ship orbiting the planet (the task inventory also accommodates returning to the orbiting space ship in the same Mars Excursion Vehicle in which the crew arrived). Most of the pre-positioned equipment will remain in cold storage awaiting the crew. However, the power-generating and extraction plants will be emplaced and activated remotely; the human mission will launch from Earth only after verification that the habitat and other structures are in place and that the propellant and life-support resources needed to survive and return to Earth have been produced. Following a six-month return transit, the crew will transfer from the interplanetary ship to an attached Orion-type craft as they approach Earth, undock, and then descend to Earth directly while the interplanetary ship continues on course unoccupied.

ADDITIONAL ASSUMPTIONS

The mission architecture assumes that an ascent vehicle, a surface habitat, and other equipment and structures will be sent to Mars independently of the crew. They will arrive with their own descent stages to place them at the surface landing site. Delivered to the site will be:

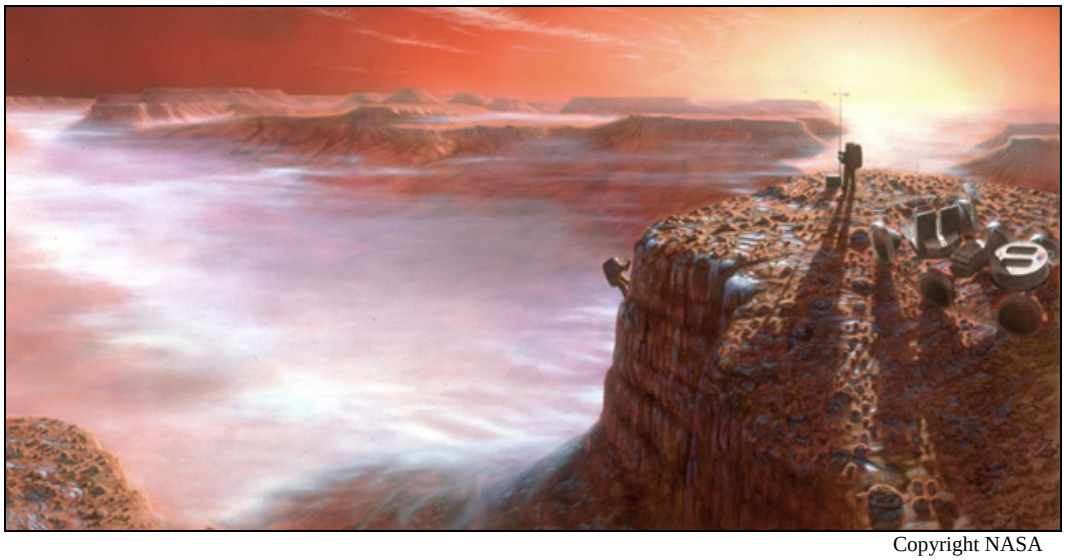
1) A Mars Ascent Vehicle for the crew to use after the 18-month surface stay to reach the interplanetary spacecraft that remains in Mars orbit.
2) A habitat structure, green house, and science laboratory that might require excavation of regolith, inflation, and deployment when the crew arrives.
3) An *In Situ* Resource Utilization (ISRU) plant that will, at a minimum, make breathing gases and water for use by the crew. This same processing technology also will be used to make propellants for use by surface transportation vehicles and by the ascent vehicle. The crew will not depart from Earth unless the automated production of water, fuel, and other resources on Mars has been verified.

4) A nuclear power plant to provide the energy needed to operate surface systems.
5) A thermal control system to support the heat-rejection needs of the surface systems.
6) Other supporting infrastructure that is either needed to support the landing of the crew or that is needed after the crew reaches the surface.

The Mars expedition crew will launch from Earth in an Earth Ascent Vehicle (EAV, an Orion capsule, most likely) and rendezvous with a pre-positioned interplanetary space craft in either Low Earth Orbit (LEO) or Cis-Lunar Orbit (CLO). Crew will transfer to the space craft and depart for Mars via Trans Mars Injection (it is possible that the EAV will remain docked to the interplanetary space craft for the journey to Mars to serve as a life boat). On the return trip, the crew will transfer from the interplanetary ship to an attached Orion-type craft five days before reaching Earth, undock, and then descend to Earth directly in an Apollo-type "skip" trajectory using parachutes and retro-rockets, while the interplanetary ship continues on course unoccupied.

NOTE ABOUT THE TASK LISTS

It is understood by the study team that the following lists of tasks are based on currently-available information and that the tools, equipment, propulsion methods, and/or other aspects of actual human expeditions to Mars might be different from those described here, as a consequence of technological development and evolving Mars Design Reference Missions.



"First Light," by Pat Rawlings, 1988.

MARS EXPEDITION TASKS BY MISSION PHASE

PHASE 1: LAUNCH TO LOW-EARTH ORBIT OR CIS-LUNAR ORBIT

The first phase of the mission begins with the crew entering the Earth Ascent Vehicle (EAV) on the launch pad and ends with the EAV docking with the interplanetary space craft in either Low-Earth Orbit (LEO) or at a Lagrange location near the Moon (i.e., Cis-Lunar, or CLO). The phase would be similar to a journey to the International Space Station (ISS) if the destination were in LEO (24 to 48 hours) and longer if the interplanetary space craft were to be waiting in CLO (75 hours). Assume 84 hours (which is slightly longer than the time required for Apollo 11 to reach the Moon for this mission phase. Launch to LEO or CLO.

Conduct communications checks and communicate observations/evaluations to other crew and MCC personnel, verbally using communications system.

- Conduct communications checks with other crew, wearing pressure suit, to prepare for launch from Earth.
- Conduct communications checks with ground personnel, wearing pressure suit, to prepare for launch from Earth.
- Communicate observations/evaluations to other crew and MCC personnel, verbally using communications system.

Enter vehicle and take position, manually while wearing pressure suit and helmet, to prepare for launch from Earth.

- Enter vehicle via diving board and ingress/egress straps, manually while wearing pressure suit and helmet, to prepare for launch from Earth.
- Conduct final predeparture inspections of storage and equipment, visually, prior to launch from Earth.
- Move (translate) to crew seat, wearing pressure suit, to prepare for launch from Earth.

Adjust controls, manually with gloved hands, before and after launch.

- Adjust control, manually with gloved hand, to reconfigure ECLS/change cabin temperature.
- Press edge key/button and F1 panel switch, manually with gloved hand, to activate LCG Pump.
- Press edge key/button with gloved hand to cycle to fresh PSA swing bed.
- Press edge key/button, with gloved hand, to activate Air Revitalization System (ARS)/Suit Mode.

Perform suit-related tasks before and after launch.

- Secure seat restraints, wearing pressure suit/gloves, to prepare for launch from Earth.
- Attach umbilicals (GSE air) to suit, manually while wearing pressure suit/gloves, to prepare for launch from Earth.
- Secure umbilicals with URDs, manually while wearing pressure suit/gloves, to prevent damage during launch.
- Install emergency O2 bottles on crew leg, manually, with help of support personnel.
- Connect to AIU, manually while wearing pressure suit/gloves, to prepare for launch from Earth.
- Conduct final suit leak check, manually with help of support personnel, to verify suit integrity.
- Release flail restraints and harness, manually, to prepare for removing pressure suit and helmet.
- Remove pressure suit/helmet, manually, to prepare for cruise to orbit.

Use Earth Ascent Vehicle (EAV) waste management system for liquid/solid waste (i.e., toilet/bodily function).

- Use Earth Ascent Vehicle (EAV) waste management system for liquid waste (i.e., toilet/bodily function).
- Use Earth Ascent Vehicle (EAV) waste management system for solid waste (i.e., toilet/bodily function).

Use emergency materials to contain/clean results of motion sickness during/after launch.

- Access and open emesis bag located in pressure suit/seat pocket, manually with gloved hand, to prepare for barfing.
- Access disposable towel located in seat pocket, manually with gloved hand, to prepare for cleaning barf from face/helmet/visor.

Prepare/eat meal, manually, using Earth Ascent Vehicle (EAV) food hydration/heating equipment/galley during cruise to LEO/CLO.

- Prepare meal for crew consumption, manually, using Earth Ascent Vehicle (EAV) food hydration/heating equipment.
- Eat/drink meal in Earth Ascent Vehicle (EAV) during cruise to LEO/CLO.

Enter control inputs, manually/visually with gloved hand, to configure and operate Earth Ascent Vehicle (EAV) before and after launch.

- Perform controls/switch checklist, visually/manually while wearing pressure suit/gloves, to verify proper configuration.

Perform ASP/flight crew check, manually while wearing pressure suit/gloves, to ensure hard switches are still in expected configuration after strap in.
Inspect display, visually wearing suit/helmet, to verify all pyros are armed for ascent.
Enter control inputs, manually/visually with gloved hand, to configure launch displays.
Enter control inputs, manually, to activate ATP/star tracker for cruise to LEO/CLO.
Enter control inputs, manually, to align IMU if necessary.
Enter control inputs, manually to override automated system, to reconfigure CM/SM heaters if necessary.
Activate controls, manually while wearing pressure suit/gloves, to configure cabin lighting.
Activate cabin pressure control, manually after visor opening, to prepare for cruise to orbit.
Respond to communications and displays, wearing pressure suit, to prepare for launch from Earth.
Activate controls, manually, to override automated process to initiate/control solar array deployment sequence, if necessary.

Monitor displays and verify configurations before and during launch to LEO/CLO

Observe crew position displays and activate controls, wearing pressure suit, to prepare for launch from Earth.
Monitor audio communications and displays, wearing pressure suit/helmet, to prepare for launch from Earth.
Monitor displays, visually while wearing pressure suit/helmet, to verify system configuration formats and eProc.
Monitor displays, visually, to assess solar array deployment status.
Monitor/control external video camera, visually/manually, to verify solar array deployment.
Monitor display, visually, to verify solar array power generation/battery charging.
Monitor displays/communicate values, visually/verbally, to evaluate system and crew readiness for orbit operations.
Monitor engine performance displays, visually wearing pressure suit/helmet, to ensure proper functioning during buffeted ascent.
Monitor displays, visually wearing pressure suit/helmet, to verify LAS jettison during buffeted ascent.
Monitor displays, visually wearing pressure suit/helmet, to verify MECO during buffeted ascent.
Monitor displays, visually wearing pressure suit/helmet, to verify core stage separation during buffeted ascent.
Monitor audio communications and displays, wearing pressure suit/helmet, during buffeted launch from Earth.
Monitor displays, visually, to verify star tracker configuration/status.

Assess displayed information, cognitively, to determine readiness to launch to LEO/CLO.

Evaluate displayed/communicated information, cognitively, to assess readiness for orbit operations.
Evaluate alarms and displays, cognitively, to identify any mission-critical anomalies during buffeted launch from Earth.

Enter control inputs, manually/visually with gloved hand, to pilot Earth Ascent Vehicle (EAV) during launch and cruise to LEO/CLO.

Adjust controls as necessary, manually wearing pressure suit/gloves, during buffeted launch from Earth.
Activate controls, manually wearing pressure suit/gloves, to abort launch in response to evaluation data during buffeted ascent.
Activate controls, manually wearing pressure suit/gloves, to override automated systems/control space craft in response to evaluation data during buffeted ascent.
Adjust main engine controls, manually wearing pressure suit/gloves, to maneuver Earth Ascent Vehicle (EAV) to correct location near space craft in LEO/CLO.
Adjust main engine controls, manually wearing pressure suit/gloves, to shut down Earth Ascent Vehicle (EAV) main engine near space craft in LEO/CLO.
Adjust attitude control thrusters, manually wearing pressure suit/gloves, to dock Earth Ascent Vehicle (EAV) to space craft in LEO/CLO.
Adjust attitude control thrusters, manually wearing pressure suit/gloves, to maneuver Earth Ascent Vehicle (EAV) to space craft in LEO/CLO.
Adjust controls, manually wearing pressure suit/gloves, to shut down attitude control thrusters and other systems after docking with space craft in LEO/CLO.
Enter control inputs, manually wearing pressure suit/gloves, to activate engine shut down if auto shut down fails, to ensure safing of EAV after docking.
Activate appropriate controls in response to alarms, manually, while communicating actions to crew and MCC during buffeted launch from Earth.

PHASE 2: PRE-TRANS MARS INJECTION AND TRANS MARS INJECTION

The second phase of the mission begins with the Mars crew entering the interplanetary space craft where they will be greeted by a team of astronauts who have prepared the ship for the journey to Mars and who will return to Earth in either the EAV or a similar space vehicle. This phase ends when the engines are shut down after the burn to achieve the correct course for the cruise to Mars. Assume a duration of four days for this mission phase, which will include final preparations and culminate with the main engine burn of approximately 60 minutes.

Conduct communications checks and communicate observations/evaluations to other crew and MCC personnel, verbally using communications system.

- Conduct communications checks with other crew, wearing pressure suit, to prepare for departing LEO/CLO.
- Conduct communications checks with ground personnel, wearing pressure suit, to prepare for departing LEO/CLO.
- Communicate observations/evaluations to other crew and MCC personnel, verbally using communications system.

Enter vehicle and take position, manually while wearing pressure suit and helmet, to prepare for launch from LEO/CLO.

- Open space craft hatch, wearing pressure suit, to prepare for entering prior to departing LEO/CLO.
- Enter space craft hatch, wearing pressure suit, to prepare for departing LEO/CLO (i.e., Trans-Mars Injection).
- Move (translate) to crew seat, wearing pressure suit, to prepare for departing LEO/CLO.
- Secure seat restraints and umbilicals, wearing pressure suit, to prepare for departing LEO/CLO.
- Conduct final predeparture inspections of storage and equipment, visually, prior to departing LEO/CLO.

Monitor displays and verify configurations before and during Trans Mars Injection (TMI)

- Observe crew position displays and activate controls, wearing pressure suit/gloves, to prepare for departing LEO/CLO.
- Monitor communications, aurally while wearing pressure suit/helmet, to prepare for departing LEO/CLO.
- Monitor displays, visually while wearing pressure suit/helmet, to prepare for departing LEO/CLO.
- Monitor communications, aurally wearing pressure suit/helmet, during departure burn from LEO/CLO.
- Monitor displays, visually wearing pressure suit/helmet, during departure burn from LEO/CLO.

Assess displayed information, cognitively, to determine readiness for TMI maneuver.

- Evaluate alarms and displays, cognitively, to identify any mission-critical anomalies.

Adjust controls/attachments, manually with gloved hands, to configure suit and displays before, during, and after launch from LEO/CLO.

- Activate appropriate controls in response to alarms, manually wearing pressure suit/gloves, while communicating actions to crew and MCC.
- Respond to communications and displays, wearing pressure suit, to prepare for departing LEO/CLO.
- Adjust controls as necessary, wearing pressure suit/gloves, during departure burn from LEO/CLO.
- Activate controls, manually wearing pressure suit/gloves, to abort TMI in response to evaluation data.
- Activate controls, manually wearing pressure suit/gloves, to override automated systems/control space craft in response to evaluation data.

PHASE 3: CRUISE TO MARS

The third phase of the mission is the unpowered cruise to Mars, which will take approximately 180 days (i.e., six months). The crew will be busy during this phase exercising and performing training tasks using configurable simulators; some refresher training will be performed, but most of the training will be new (in response to a strategy to transfer much of the pre-launch training burden to the cruise phase).

Conduct communications checks/communicate observations/evaluations to other crew and MCC personnel, verbally using comm system during Cruise to Mars.

- Operate communications system, manually, to receive transmission from MCC.
- Operate communications system, manually, to transmit message to MCC.
- Speak with other members of the crew concerning technical and task-related topics.
- Speak with other members of the crew concerning non-technical and non-task-related topics.
- Perform interviews and Public Affairs Office (PAO) events, using communications system, to inform Earth public of progress.
- Transmit data collected during the Transit of Earth to ground stations immediately following event.

Interact with crew mates, personally, concerning task performance.
Interact with crew mates, personally, concerning non-task-related matters.
Compose/record electronic/video journal, using keyboard/computer in space craft, to create/preserve personal account of experiences.
Conduct physical/cognitive tests in space craft to assess fitness for duty (automatically-scheduled/results transmitted to Earth).

Conduct EVA to perform maintenance or retrieve items from outside the interplanetary space vehicle during Cruise to Mars.

Don pressure suit in response to meteor penetration or hull breech alarm, manually, with crew members helping each other.
Conduct EVA for maintenance or to retrieve needed supplies/equipment/expertise.
Remove and stow pressure suit following departure burn from LEO/CLO (i.e., Trans-Mars Injection).

Use interplanetary space vehicle waste management systems for liquid/solid waste (i.e., toilet/bodily function) during Cruise to Mars.

Use space craft waste management system for liquid waste (i.e., toilet/bodily function).
Use space craft waste management system for solid waste (i.e., toilet/bodily function).

Use interplanetary space vehicle hygiene systems for cleaning during Cruise to Mars.

Activate hygiene system to enable hand and body washing.
Shave face, manually using safety razor/soap/water, to remove beard growth.
Shave face, manually using electric razor, to remove beard growth.
Cut hair, manually using clippers/scissors/comb/vacuum tube, to remove excess hair growth.
Operate hygiene system to clean/disinfect hands and body.
Operate hygiene system to clean/brush teeth.
Retrieve wet wipes, towel, and clothing to clean body after exercise in preparation for study and work-related tasks.
Remove personal garments from storage in preparation for changing clothes.
Doff (remove) soiled garments and don clean clothing.
Insert soiled garments in collection container to dispose.

Maintain space craft waste management systems during Cruise to Mars.

Remove and replace bio collection container from waste management system, manually, to ensure continuity of operation.
Discard packaging waste in trash compactor, manually, to clear galley.
Operate trash compactor, manually, to increase space for additional packaging waste.
Remove compacted packaging waste from trash compactor, manually, and transport to onboard storage.
Insert new sanitary liner in trash compactor, manually, to prepare for additional use.

Prepare/eat meal, manually, using interplanetary space vehicle food hydration/heating equipment/galley during cruise to Mars during Cruise to Mars.

Transfer food packages from deep storage to proximal storage, manually, to prepare galley for crew use.
Activate food hydration/heating equipment, manually, to prepare galley for crew use.
Prepare meal for crew consumption, manually, using space craft food hydration/heating equipment.
Eat meal together with other members of the crew in the space craft ward room/galley.

Conduct recreational activities, individually and as a crew, during Cruise to Mars.

Read articles, books, etc., during leisure periods for recreation.
Listen to music individually during leisure periods for recreation.
Listen to music individually while exercising for recreation.
Watch video (movies, TV programs, documentaries, etc.) individually while exercising for recreation.

Watch video (movies, TV programs, documentaries, etc.) individually during leisure periods for recreation.
Watch video (movies, TV programs, documentaries, etc.) together with other crew members during leisure periods for recreation.
Play chess and other board games together with other crew members during leisure periods for recreation.
Play chess with MCC personnel and others on Earth during leisure periods for recreation.

Sleep during cruise phase for approximately eight hours each 24-hour period, during Cruise to Mars.

Retrieve sleeping bag from storage and attach bag to davits in sleep chamber to prepare for sleep period.
Enter secured sleeping bag and begin sleep period to restore cognitive/physical functioning.

Conduct inventories and update records during Cruise to Mars.

Conduct and maintain inventories of consumable supplies, visually/manually (e.g., food, water, O2), to update records.
Conduct and maintain inventories of spare parts and materials, visually/manually, to update records.

Exercise daily using onboard equipment during Cruise to Mars.

Configure resistive device and perform exercise to maintain cardiovascular conditioning, muscle strength, and bone density.
Mount bicycle ergometer and perform exercise to maintain cardiovascular conditioning, muscle strength, and bone density.
Don harnesses and perform exercise using treadmill to maintain cardiovascular conditioning, muscle strength, and bone density.

Assess displayed and aural information, cognitively, to determine appropriate course of action during Cruise to Mars.

Identify Emergency Alarm (i.e., Loss of pressure, Fire, Toxic substance/emission) and develop repair/recovery plan.
Identify Caution/Warning Alarm (e.g., CO2, ECLS, Navigation) and develop repair/recovery plan.

Respond to technical emergencies, following procedures and with equipment provided, during Cruise to Mars.

Retreat to shielded area of space craft with other members of the crew in response to critical radiation event warning.
Remain in shielded area of space craft with other members of the crew during critical radiation event.
Respond to space craft fire alarm.
Respond to space craft micro-meteorite impact alarm.
Identify precise location of meteor penetration/hull breech, visually/aurally, assess severity, and determine method(s) to stop loss of pressure.
Retrieve repair kit from storage and carry to location of meteor penetration or hull breech.
Apply patch and adhesive material to meteor penetration site, manually, to close leak.
Retrieve and don protective fire-fighting ensemble, manually, to prepare for fire emergency.
Remove fire extinguisher from bulkhead bracket and manually carry to source of fire.
Point fire extinguisher nozzle at burning material and activate system manually while wearing protective ensemble to suppress fire.
Respond to space craft hull breech alarm.
Respond to space craft toxic substance/outgassing alarm.
Respond to space craft CO2 alarm.
Respond to space craft general ECLS failure alarm.
Respond to space craft navigation alarm.

Respond to dental emergencies, following procedures and with equipment provided, during Cruise to Mars.

Conduct dental examination on crew member, manually/visually, to investigate complaint of tooth/jaw pain.
Interpret results of dental examination, cognitively with MCC consultation, to identify source of apparent tooth/jaw pain.
Prepare dental adhesive, fit, apply adhesive, and replace crown.
Administer pain medicine (Eugenol), manually as needed, to treat a crewmember's fractured tooth showing exposed pulp.

Apply direct pressure and hold until bleeding stops to treat loss of tooth of a crewmember.

Administer medication and if pain severe perform dental nerve block to treat crewmember's dental pain.

Apply temporary tooth filling and smooth excess (instruct patient to limit solid food consumption on affected side of mouth for 12-24 hours) to repair dental filling.

Perform medical diagnoses and evaluations, cognitively, during Cruise to Mars.

Diagnose medical condition, cognitively and verbally through interviews with conscious ill or injured crewmember and physical exam.

Evaluate unresolved sleep disorder, cognitively per procedures, to diagnose problem and identify treatment/intervention.

Perform tests and examinations, physically, to support medical diagnoses during Cruise to Mars.

Collect vitals from injured/ill crew (e.g. temp, pulse, oxygen saturation, respiration rate, blood pressure) with tools in kit, reassess as treatments/meds are administered.

Use medical software along with vitals/test results to help diagnosis condition of conscious or unconscious injured/ill crewmember.

Take image of the back of the eye, manually using a retinal camera (fundus exam), to test for visual impairment and/or increased intracranial pressure (VIIP).

Perform decompression sickness examination with the aid of an electronic form to determine if treatment is needed.

Collect Electrocardiogram (ECG) wave properties data with ECG hardware and leads placed on the patient for analysis of heart rate and variability.

Perform initial evaluation/treatment of chest pain by administering Aspirin, delivering oxygen with respiratory equipment, collecting vitals/ECG, and listening to lungs.

Check for capillary refill and pulses below injury location, apply splint, secure with ACE bandage to treat injured extremity (e.g., leg, arm).

Measure pulse and respiratory rate, administer oxygen and inhaled Albuterol, perform chest exam, and obtain blood pressure to treat difficulty breathing.

Obtain vital signs and photo-document rash, injury or other ailments to perform periodic health evaluation of a crewmember.

Test near and far visual acuity, visual field, contrast sensitivity, and potential cornea abrasions using a Panoptic tool to examine eyes.

Apply blood pressure device and monitor to assess patient's blood pressure.

Examine patient, manually/cognitively, to diagnose lower extremity stress fracture; proscribe reducing weight-bearing activities (exercise in microgravity/walking in partial).

Collect sample via swab and perform culture, manually, to test for bacterial infection.

Collect samples of blood/urine/saliva, manually, to prepare for lab tests.

Conduct lab tests (e.g., CBC, chemical panels, strep throat), manually on collected samples, to help diagnose medical problem.

Respond to medical emergencies, following procedures and with equipment provided, during Cruise to Mars.

Clear airway obstruction of choking/conscious crew by abdominal thrusts from behind patient with fist below ribcage pulling inward and upward until object clears.

Treat patient who becomes unconscious from choking by attempting to clear foreign object manually/pinch nose/apply breaths and begin CPR.

Perform CPR on unconscious /not breathing crewmember and determine if additional actions are needed as apart of Advanced Cardiac Life support.

Perform defibrillation on unconscious electrically isolated crewmember using AED to restore heartbeat.

Insert catheter in the bladder to drain urine (self-catheterize) for urine retention.

Administer traction and counter-traction until finger slips back in place to relocate a dislocated finger.

Administer traction and counter-traction until shoulder slips back in place to relocate a dislocated shoulder

Insert staples, sutures, or Derma bond depending on type and location of cut to repair skin laceration.

Insert catheter into pleural space between lung/chest wall, producing a pathway for air to escape to perform a needle decompression of a pneumothorax (collapsed lung).

Insert an IV catheter and secure with medical tape to provide intravenous access for medications and fluids.

Attach prepared fluid set to an inserted IV catheter tp administer IV fluids and medications.

Perform surgery, manually using available instruments, to repair a detached retina.

Perform surgery, manually using available instruments, to repair a compound fracture of arm or leg bone.

Perform surgery, manually using available instruments, to treat acute appendicitis.

Implement countermeasures (e.g., counseling, software) if symptoms of maladjustment or degraded behavioral health are detected among crew personnel.

Administer medications during Cruise to Mars.

Administer medications or an intramuscular shot (e.g. Epipen) to treat an allergic reaction.
Administer medication to suppress seizure/avoid loss of consciousness and uncontrolled muscle contractions.
Administer intramuscular shot, take vitals, and administer oxygen as needed to protect patient from injury from seizure.
Administer medications (e.g., antibiotics, antidiarrheal, antihistamine, decongestants, lubricants, pain relievers, sleep, steroids, stimulants and stool softeners) for conditions.
Administer hydrocodone and acetaminophen (Vicodin HP) and notify CMO to treat pain.
Administer Lidocaine or Epinephrine with a syringed needle, then create opening with scalpel to drain, to treat skin or dental abscess.
Apply a thin layer of Mupirocin (Bactroban) ointment and bandage affected areas to treat burned skin.
Deliver medication to the lungs with inhaler by patient closing lips around inhaler, inhaling slowly, holding breath for 10 secs and removing inhaler from mouth and exhaling.
Apply medical drops into the ear canal to treat ear pain caused by blockage (i.e., Barotrauma) that is not alleviated by yawning or chewing.
Administer antibiotics, manually per instructions, to treat ear infection.
Administer antibiotic ointments/drops, manually per instructions, to treat eye irritations/abrasions/infections.
Administer appropriate antibiotic (oral or IV) to treat confirmed bacterial infection.
Administer epinephrine, oxygen, IV antihistamines and cortisone, and beta-agonist (e.g., Albuterol), manually, to treat anaphylaxis.
Administer sedative, manually via syringe, to treat crewmember experiencing a behavioral emergency.
Administer anti-inflammatory drugs, manually, to immobilized crewmember to treat spinal cord trauma.
Administer IV antibiotics, manually, to treat sepsis (administer vasopressor medication if blood pressure remains low).

Perform medical treatments during Cruise to Mars.

Irrigate eye and perform eye exam to treat chemical exposure to a crewmember's eye.
Minimize eye and skin exposure to toxics to prepare for treating exposed crewmate.
Remove exposed crewmates soiled clothes, particles/liquid and irrigate with water (flush eye with water) for respiratory exposure/follow Difficulty breathing procedure.
Place PHA QDM on crewmember, deliver oxygen for 2 hours, hydrate 1 liter per hour for 2 hours or as tolerated to treat decompression sickness.
Remove staples using a skin staple remover to complete repair.
Remove sutures with medical scissors to complete repair.
Insert Oral Airway device halfway into mouth and rotate 180 degrees before inserting until it is flush against the lips to aid ventilation of unconscious patient.
Place Ambu Bag mask over nose and mouth and gently squeeze bag to deliver breaths every 5 to 8 seconds to assist temporary ventilation of a compromised patient.
Deliver oxygen to a respiratory distressed patient by automated ventilation provided in a respiratory support pack.
Pinch fleshy part of nose, manually, for 10 minutes to stop nose bleeding.
Insert nasal packing and drops, manually per instructions, to stop persistent nose bleeding.
Remove wax from ear, manually using curette/medical drops, to treat ear pain.
Clean fingernail, apply antibiotic ointment, cover with adhesive bandage, manually until a new nail grows, to treat/protect fingernail damage from EVA.
Apply ice (multiple sessions) and administer pain medication as needed, manually, to treat back/shoulder/neck sprain/strain.
Apply ice/cold pack and compress with bandage, manually, to treat wrist, elbow, ankle, or knee sprain/strain.
Apply splint, manually, to treat unresolved wrist, elbow, ankle, or knee sprain/strain.
Drain sinus passageway (with nasal spray) and administer antibiotics, manually, to treat acute sinusitis.
Secure Airway, Breathing, Circulation (ABCs)/perform physiological monitoring (e.g., Vitals and Chem Labs), manually and cognitively, to manage acute radiation syndrome.
Apply physical force and binding/duct tape, manually with the help of another crew member, to restrain a crewmember experiencing a behavioral emergency.
Perform a reduction maneuver gently and slowly, manually with the assistance on another crewmember, to realign a dislocated elbow.

Secure crewmember to a flat surface, manually using restraints, to immobilize for treatment of suspected spinal cord trauma.

Apply cast, splint, or brace to extremity (e.g., arm, leg), manually, to immobilize simple fracture.

Perform administrative functions during Cruise to Mars.

Coordinate exercise device availability among crew to ensure access to maintain cardiovascular conditioning, muscle strength, and bone density.

Coordinate simulator availability among crew to ensure refresher training for all required skills and functions.

Coordinate crew response to meteor penetration, hull breech, fire, ECLS, or other emergency.

Monitor individual behavioral health by speaking with each crew member with the goal of identifying symptoms of maladjustment.

Schedule tasks and monitor performance of work to ensure that opportunities and resources are allocated appropriately among crew personnel.

Plan operations (e.g., EVA, maintenance of external components) using computer-based records in consultation with MCC and onboard personnel.

Conduct science and planning functions during Cruise to Mars.

Review expedition geology program objectives and procedures, using onboard resources, to prepare for surface operations.

Review expedition biology program objectives and procedures, using onboard resources, to prepare for surface operations.

Assemble equipment needed to observe and record the Transit of Earth that will occur on day 73 after TMI.

Conduct astronomical observations, photography, and remote sensing to occupy cruise time with meaningful activity.

Conduct life science experiments to occupy cruise time with meaningful activity.

Activate equipment, observe, and record the eight-hour Transit of Earth on day 73 after TMI.

Conduct and record solar observations using onboard equipment and telescopes.

Conduct and record planetary and stellar observations using onboard equipment and telescopes.

Conduct and record radio astronomy observations using onboard equipment and telescopes.

Conduct and record Mars observations using onboard equipment and telescopes.

Conduct and record asteroid/comet observations using onboard equipment and telescopes.

Conduct and record Earth observations using onboard equipment and telescopes.

Conduct installation functions during Cruise to Mars.

Enter control inputs, manually, to configure space craft computer to support training simulation and task preparation.

Deploy supports/structures, manually, to configure dedicated area of space craft for medical procedure.

Modify pressure suit to adjust length of torso segment in response to spine elongation in zero gravity.

Enter control inputs, manually, to load software patch/reload software.

Program 3-D printer, manually via computer inputs, to fabricate a replacement part for a mechanical system onboard space craft.

Operate 3-D printer, manually via computer inputs, to fabricate a replacement part for a mechanical system onboard space craft.

Remove and trim object fabricated by 3-D printer, manually using hand tools, to prepare replacement part for a mechanical system onboard space craft.

Conduct maintenance functions during Cruise to Mars.

Review schematics and other documentation, visually, to isolate electronic fault in space craft.

Review schematics and other documentation, visually, to isolate plumbing (e.g., cooling, CLSS) fault in space craft.

Insert test equipment probes in electronic components, manually, and observe displays, visually, to isolate electronic fault in space craft.

Inspect circuit board, visually, to identify short circuit or loose/missing connection in space craft.

Inspect circuit board, visually, to identify scorching that might indicate degraded/faulty/failed electronic component in space craft.

Review documentation/enter control inputs, visually/manually, to diagnose software problem.

Inspect plumbing (e.g., cooling, CLSS), visually and with hand tools, to identify source of plumbing fault in space craft.

Remove and replace plumbing component (e.g., section, valve), using hand tools and schematics, to restore system functionality in space craft.
Retrieve spare parts/materials (e.g., valve, duct tape) from storage and move to work site in space craft, manually, to prepare for troubleshooting/repair.
Cut pipe, manually using hand saw, to remove damaged section of space craft plumbing.
Insert new section of pipe and attach in place, manually, using electric soldering tool, flux, and solder to repair space craft plumbing.
Remove 1 meter of duct tape from roll, manually, to temporarily repair leaking hose/fitting.
Wrap 1 meter of duct tape around hydraulic hose/fitting, manually, to temporarily repair leak.
Replace electronic connector on wire/cable, manually, using hand tools and spare parts.

Conduct navigation functions during Cruise to Mars.

Use sextant and star charts to estimate space craft position and course to compare to computerized navigation system.
Use sextant and star charts to estimate space craft position and course if computerized navigation system fails.
Convert results of manual navigation fix to propulsion changes necessary to achieve MOI, using tables and other calculation references.

Conduct piloting functions during Cruise to Mars.

Operate propulsion controls, manually, to maneuver space ship in preparation for ship-to-ship EVA.
Deploy and operate robot, remotely during cruise phase, to inspect external features of space craft.
Deploy and operate robot, remotely during cruise phase, to repair external features of space craft.

Monitor systems to ensure proper functioning during Cruise to Mars.

Monitor system displays, visually, to verify normal functioning of *life support system*.
Monitor system displays, visually, to verify normal functioning of *navigation system*.
Monitor system displays, visually, to verify normal functioning of *propulsion/attitude control syste*m.
Monitor system displays, visually, to verify normal functioning of *communication system*.
Monitor radiation-detection systems, visually/aurally, for evidence of Solar Proton and Galactic Cosmic Ray Events (SPE/GCR).
Monitor space craft atmosphere, visually/manually, by checking displays and comparing values to reference documents.

Adjust systems to ensure proper functioning during Cruise to Mars.

Adjust controls, manually per procedures, to maintain normal functioning of *life support system*.
Adjust controls, manually per procedures, to maintain normal functioning of *navigation system*.
Adjust controls, manually per procedures, to maintain normal functioning of *propulsion/attitude control system*.
Adjust propulsion/attitude control system controls, manually, to maintain proper course to Mars Orbit Injection (MOI).
Adjust controls, manually per procedures, to maintain normal functioning of *communication system*.
Adjust space craft atmosphere, manually, by making computer input commands in response to displays and reference documents.

Conduct primary and refresher training to learn/preserve skills during Cruise to Mars.

Review procedures for emergency mission abort (periodically during first third of cruise phase).
Review emergency procedures for various possibilities (fire, micro-meteorite impact, hull breech, outgassing, ECLS failure, etc.).
Conduct (training) simulation using space craft computer to refresh piloting skills for Mars Orbit Injection.
Conduct (training) simulation using space craft computer to refresh navigation skills for Mars Orbit Injection.
Conduct (training) simulation using space craft computer to refresh communication skills for Mars Orbit Injection.
Conduct primary training using digital media and space craft computer to learn information and skills that were not included in pre-mission training.
Read procedures and technical information to prepare for conducting tasks during cruise, MOI, and descent to planet.

PHASE 4: MARS ORBIT INJECTION

The fourth phase of the mission assumes six days of intermittent preparation as the interplanetary space craft approaches Mars and the crew makes final course corrections. This phase ends with 12 hours of high-tempo activity preceding a 60-minute main engine burn to slow the ship, which will be pointed in the opposite direction of travel.

Conduct communications checks and communicate observations/evaluations to other crew and MCC personnel, verbally using communications system.

Receive final course-correction information from MCC to prepare for aerobraking maneuver to achieve MOI.

Communicate status of systems during aerobraking maneuver and aerocapture in heavy buffeting to achieve MOI.

Prepare for Mars Orbit Insertion aerobraking maneuver.

Don pressure suit, manually with the help of one other crew member, in preparation for aerobraking maneuver to achieve MOI.

Stow and secure all equipment, manually per load plan, to prepare space craft for aerobraking maneuver to achieve MOI.

Attach to individual crew maneuver position, while wearing pressure suit, in preparation for aerobraking maneuver to achieve MOI.

Monitor systems during Mars Orbit Insertion.

Monitor automatic firing of retro rockets, visually, for aerobraking maneuver to achieve MOI.

Monitor displays during aerobraking maneuver and aerocapture in heavy buffeting to achieve MOI.

Perform piloting functions during Mars Orbit Insertion.

Configure space craft computers in preparation for aerobraking maneuver to achieve MOI.

Override automatic firing of retro rockets for aerobraking maneuver to achieve MOI if automated system fails.

Adjust controls (retro rockets, attitude thrusters), manually, to achieve MOI.

PHASE 5: MARS ORBIT

The fifth phase of the mission begins as the interplanetary ship approaches and then docks with a pre-positioned Mars Descent Vehicle (MDV), which is located in an elliptical orbit with a 1-Sol (one Martian day) period; the orbit places the space craft over the landing site once per Martian day at the same time of day. Assume approximately 48 hours for the rendezvous and docking and another 48 hours for the crew to enter the Mars Descent Vehicle (MDV), configure systems, perform final checks, and communicate with Earth in preparation for descent to the surface of Mars.

Conduct communications checks and communicate observations/evaluations to other crew and MCC personnel, verbally using communications system.

Communicate status of space craft and systems to crew, verbally using communications equipment, to advise of conditions.

Communicate status of space craft and systems to MCC, verbally using communications equipment, to advise of conditions.

Communicate status of systems to MCC, verbally/manually (text) during Mars Orbit operations to advise of conditions.

Review procedures/checklists to prepare for Mars Orbit Operations and descent.

Review checklists, visually/verbally, with other crew members to verify that all procedures have been completed to secure for Mars Orbit operations.

Conduct final preparation/training tasks to prepare for Mars Surface Descent.

Configure systems for Mars Orbit operations and descent.

Configure space craft computers in preparation for Mars Orbit operations.

Detach from individual crew maneuver position, while wearing pressure suit, in preparation for Mars Orbit operations.

Doff pressure suit, manually with the help of one other crew member, in preparation for Mars Orbit operations.

Transfer to Mars Excursion Vehicle (MEM)/Mars Descent Vehicle (MDV), physically while wearing pressure suit, to prepare for descent maneuver.

Monitor systems during Mars Orbit operations

View displays, visually, to verify aerobraking maneuver has achieved MOI.

Inspect space craft displays and equipment, visually/manually, to identify any apparent damage from aerobraking maneuver.

Monitor system displays, visually, to ensure nominal functioning during Mars Orbit operations.

Perform piloting functions during Mars Orbit operations

Adjust attitude and propulsion controls, manually, in response to navigation/attitude control data, to achieve/maintain proper Mars Orbit.

Adjust attitude and propulsion controls, manually, in response to navigation/attitude control data, to dock with pre-positioned Mars Descent Vehicle.

PHASE 6: MARS SURFACE DESCENT

The sixth phase of the mission begins with the crew securing themselves in the Mars Descent Vehicle (MDV) where they will perform final checks before undocking from the interplanetary space craft and then initiating the deorbit burn at the highest point of the parking orbit (apoapsis). The MDV will descend through half of the parking orbit (about 12 hours) at the end of which is atmospheric entry and the 10 to 20-minute terminal descent burn. Assume approximately 14 hours from ingress in Mars orbit to egress of the MDV following landing, shut-down of MDV systems, and initial communications from the planetary surface.

Conduct communications checks and communicate observations/evaluations to other crew and MCC personnel, verbally using communications system.

Receive final thrust and duration information from MCC to prepare for Mars Surface Descent maneuver.

Communicate status of systems during Mars Surface Descent maneuver in heavy buffeting to depart Mars Orbit for surface.

Communicate system status, verbally to crew members using internal communications equipment, during controlled descent.

Communicate system status, verbally to MCC using external communications equipment, during controlled descent.

Communicate successful touch down, verbally and via text, to MCC using external communications equipment to confirm status.

Communicate systems shut down and safing to crew via internal communication system to advise of status.

Communicate systems shut down and safing to MCC via external communication systems to advise of status.

Prepare for Mars Surface Descent maneuver.

Stow/secure all equipment, manually per load plan, to prepare Mars Excursion Vehicle (MEV)/Mars Descent Vehicle (MDV) for Mars Surface Descent maneuver.

Don pressure suit, manually with the help of one other crew member, in preparation for Mars Surface Descent maneuver.

Attach to individual crew maneuver position (i.e., seat), while wearing pressure suit, in preparation for Mars Surface Descent maneuver.

Inspect Mars Excursion Vehicle (MEV)/Mars Descent Vehicle (MDV) to verify that systems are go for descent maneuver.

Monitor systems during Mars Surface Descent.

Monitor automatic firing of Mars Excursion Vehicle (MEV)/Mars Descent Vehicle (MDV) retro rockets, visually, for Mars Surface Descent maneuver.

Monitor displays during Mars Surface Descent maneuver in heavy buffeting to depart Mars Orbit for surface.

View displays for parachute, aero shell, and retro rocket to verify correct functionality at appropriate times to ensure controlled descent to surface.

View displays, visually during buffeted descent, to assess proximity and verify touch down on planetary surface.

Verify automated engine shut down by visually monitoring displays to ensure safing of Mars Excursion Vehicle after touch down.

Verify automated landing system shut down by visually monitoring displays to ensure safing of Mars Excursion Vehicle after touch down.

Perform piloting functions during Mars Surface Descent.

Enter control inputs, manually wearing pressure suit/gloves, to configure Mars Excursion Vehicle computers for Mars Surface Descent maneuver.

Enter control inputs, manually wearing pressure suit/gloves, to detach Mars Excursion Vehicle (MEV)/Mars Descent Vehicle (MDV) from space craft.

Enter control inputs, manually wearing pressure suit/gloves, to maneuver Mars Excursion Vehicle (MEV)/Mars Descent Vehicle (MDV) away from space craft.

Enter control inputs, manually, to override automatic firing of retro rockets for Mars Surface Descent maneuver if automated system fails.

Adjust parachute, aero shell, and retro rocket controls in response to system displays to manually override automatic systems, if necessary.

Adjust retro rocket controls, manually during buffeted descent, to maneuver MEV/MDV to correct location near pre-positioned Mars Surface Habitat.

Adjust controls, manually, to shut down retro rocket and other systems after touch down on planetary surface.

Enter control inputs, manually wearing pressure suit/gloves, to activate engine shut down if displays indicate failure of automated shut down after touch down.

Enter control inputs, manually wearing pressure suit/gloves, to activate landing system shut down if displays indicate failure of automated shut down after touch down.

Perform post-Mars Descent maneuver functions.

Enter control inputs, manually wearing pressure suit/gloves, to secure (other) flight systems after engine shut down.

Enter control inputs, manually, to convert Mars Excursion Vehicle (MEV)/Mars Descent Vehicle (MDV) from descent mode to surface mode.

Assess crew members' physical and cognitive abilities, verbally using self-reports and established diagnostics, to determine capacities for immediate work.

PHASE 7: MARS SURFACE OPERATIONS

The seventh and longest phase of the mission begins with the crew walking from the Mars Descent Vehicle (MDV) to the pre-positioned Mars Habitat following landing, and ends approximately 545 days later when the crew enters the pre-positioned Mars Ascent Vehicle (MAV) to return to Mars orbit and the interplanetary ship. Crew time on the planetary surface will be spent performing construction and maintenance; housekeeping and planning; geological and biological science in the vicinity of the habitat and during mechanized traverses; and communicating among the members of the crew and with Earth (communications response lags with Earth will be approximately 20 minutes).

Conduct communications checks/communicate observations/evaluations to other crew and MCC, verbally using communications system during MSO.

Communicate with surface EVA crew members from surface habitat, verbally using radios, to advise and coordinate operations.

Operate surface rover communications system to transmit/receive information to/from habitat personnel.

Operate Mars habitat audio/video communications system, manually, to transmit/receive messages to/from MCC.

Operate Mars habitat email communications system, manually, to transmit/receive messages to/from MCC.

Operate Mars habitat data link communications system, manually, to transmit/receive messages to/from MCC.

Transfer digital copies of information received from MCC to portable digital device, manually, for later reference.

Print paper copies of information received from MCC, using available printer manually, for later reference, if necessary.

Prepare group communications, using audio/video equipment, to transmit to MCC.

Perform interviews and other Public Affairs Office (PAO) events, using communications system, to inform Earth public of progress.

Interact/communicate with other crew members directly during Mars Surface Operations.

Meet with other members of the crew in the Mars habitat to review research results and plan additional research activities.

Interact with crew mates, personally, concerning task performance.

Interact with crew mates, personally, concerning non-task-related matters.

Speak with other members of the crew in the surface habitat concerning technical and task-related topics.

Speak with other members of the crew in the surface habitat concerning non-technical and non-task-related topics.

Enter/exit surface habitat, manually while wearing pressure suit and helmet, during Mars Surface Operations.

Enter pre-positioned Mars habitat, on foot via airlock while wearing surface EVA suit, to prepare activation of surface habitat systems.

Assemble and don surface EVA suit in Mars habitat with help of one other crew member.

Enter airlock from surface habitat, on foot while wearing surface EVA suit, in preparation for exiting to planetary surface.

Exit surface habitat airlock, on foot while wearing surface EVA suit.

Remove dust from suit and equipment before entering surface habitat following surface EVA to minimize contamination of airlock interior.

Blow accumulated dust from surface EVA suit, using compressed gas and vacuum, while wearing surface EVA suit in airlock, to decontaminate before entering habitat.

Enter surface habitat from airlock, on foot, while wearing surface EVA suit.

Attach tether to surface EVA suit and to other crew member's suit and/or rover, manually while wearing suit in dust storm, for safety when visibility conditions warrant.

Perform initial installation/activation/inspection of surface habitat systems during Mars Surface Operations.

Activate surface habitat life support system, manually by control inputs and display verification, to switch from temporary onboard system.

Unstow, deploy, and activate waste management system in surface habitat per procedures, manually, to prepare for use by crew.

Activate hygiene system in surface habitat to enable hand and body washing.

Activate food heating equipment, manually, to prepare surface habitat galley for crew use.
Deploy surface habitat restraints, interior consoles, and equipment, manually, to prepare for crew use.
Unstow, deploy, and activate surface habitat exercise system per procedures, manually with assistance, to prepare for use by crew.
Activate, program, and adjust surface habitat audio/video capability to enable entertainment during exercise.
Deploy supports/structures, manually, to configure dedicated area of surface habitat for medical procedure.
Transfer food packages from deep storage to proximal storage in surface habitat, manually, to prepare galley for crew use.
Retrieve cosmic radiation dosimeters from storage, manually, and deploy in designated locations in surface habitat to measure cosmic radiation.
Configure habitat system, manually, to enable display of robot remote video on large screen for general crew viewing.

Use surface habitat waste management systems for liquid/solid waste (i.e., toilet/bodily function) during Mars Surface Operations.

Use waste management system in surface habitat to eliminate liquid waste.
Use waste management system in surface habitat to eliminate solid waste.

Use surface habitat hygiene systems for cleaning during Mars Surface Operations.

Operate hygiene system in surface habitat to clean/disinfect hands and body.
Shave face, manually using safety razor/soap/water, to remove beard growth.
Shave face, manually using electric razor, to remove beard growth.
Remove personal garments from surface habitat storage in preparation for changing clothes.
Remove soiled garments and don clean clothing in surface habitat.
Insert soiled garments in surface habitat collection container to dispose.
Cut hair, manually using electric razor, to remove excess growth.
Brush teeth, manually, to maintain oral hygiene.

Prepare and consume meals in surface habitat during Mars Surface Operations.

Prepare meal for crew consumption, manually, using surface habitat food heating equipment.
Prepare drink for crew consumption, manually, using surface habitat liquid dispensing system
Prepare/retrieve snack for crew consumption, manually, using surface habitat food system
Eat meal together with other members of the crew in the surface habitat ward room/galley.

Perform surface habitat housekeeping functions during Mars Surface Operations.

Conduct routine housekeeping/cleaning, manually using cloths, liquids, and vacuum, to maintain hygiene of surface habitat.
Conduct routine replenishment of stores, manually, to maintain functionality of surface habitat.
Remove and replace bio collection container from waste management system in surface habitat, manually, to ensure continuity of operation.
Discard packaging waste in surface habitat trash compactor, manually, to clear galley.
Operate surface habitat trash compactor, manually, to increase space for additional packaging waste.
Remove compacted packaging waste from surface habitat trash compactor and transport to dedicated trash storage, manually.
Insert new sanitary liner in surface habitat trash compactor, manually, to prepare for additional use.
Retrieve wet wipes, towel, and clothing from surface habitat storage to clean body after exercise in preparation for work-related tasks.

Perform recreation/leisure activities in the surface habitat during Mars Surface Operations.

Read articles, books, etc., in the surface habitat during leisure periods for recreation.
Listen to music individually in the surface habitat during leisure periods for recreation.
Listen to music individually in the surface habitat while exercising for recreation.

Watch video (movies, TV programs, documentaries, etc.) individually in the surface habitat while exercising for recreation.
Watch video (movies, TV programs, documentaries, etc.) individually in the surface habitat during leisure periods for recreation.
Watch video (movies, TV programs, documentaries, etc.) together with other crew members in the surface habitat during leisure periods for recreation.
Play chess and other board games together with other crew members in the surface habitat during leisure periods for recreation.
Play chess with MCC personnel and others on Earth while in the surface habitat during leisure periods for recreation.

Perform exercise in surface habitat to maintain cardiovascular, muscle, and bone conditioning during Mars Surface Operations.

Mount surface habitat bicycle ergometer and perform exercise to maintain cardiovascular conditioning, muscle strength, and bone density.
Don harnesses and perform exercise using surface habitat treadmill to maintain cardiovascular conditioning, muscle strength, and bone density.
Configure surface habitat resistive device and perform exercise to maintain cardiovascular conditioning, muscle strength, and bone density.

Sleep in surface habitat during Mars Surface Operations.

Enter sleeping compartment in surface habitat and begin sleep period to restore cognitive/physical functioning.

Sleep in surface rover during Mars Surface Operations.

Deploy and enter sleeping bag in surface rover to enable extended operations on planetary surface.
Sleep in surface rover to enable extended operations on planetary surface (e.g., 3 sols during drilling operations).

Use surface rover waste management systems for liquid/solid waste (i.e., toilet/bodily function) during Mars Surface Operations.

Use waste management system in surface rover for liquid waste.
Use waste management system in surface rover for solid waste.

Prepare and consume meals in surface rover during Mars Surface Operations.

Prepare meal for crew consumption, manually, using (pressurized) surface rover food dispensing equipment to enable extended operations on planetary surface.
Eat food/drink fluids in (pressurized) surface rover to enable extended operations on planetary surface.

Perform surface rover habitability/logistics functions during Mars Surface Operations.

Retrieve food/supplies from storage and stow in surface rover, manually while wearing surface EVA suit, to replenish consumables for additional operations.
Remove/replace human waste storage containers from surface rover, manually while wearing surface EVA suit when necessary, to prepare for additional operations.

Perform installation/activation/inspection of auxiliary systems during Mars Surface Operations.

Remove restraints from greenhouse equipment, manually while wearing protective gloves, to prepare greenhouse for operation.
Remove growing medium from storage and place in designated locations, manually while wearing protective gloves, to prepare for greenhouse operation.
Connect plumbing fixtures/pipes to H2O/fertilizer circulation system, manually while wearing protective gloves, to prepare greenhouse for operation.
Insert seeds in growing medium, manually while wearing protective gloves, to prepare greenhouse for operation.
Deploy sample curation console and partition/materials in sample storage module, manually, to enable curation/processing of key samples for Earth return.

Perform planning and administrative functions, individually and with other crew members during Mars Surface Operations.

Provide feedback about operations plans/timelines/work assignments to expedition leader, personally or in writing, to express concerns/opinions.
Receive feedback about operations plans/timelines/work assignments to expedition crew member, personally or in writing, to improve operations.
Review maps/charts/procedures, manually/visually, in Mars habitat to plan construction/installation tasks.
Review maps/charts/procedures, manually/visually, in Mars habitat to plan route for surface sortie/traverse and geological research.
Investigate surroundings visually with help of photographs and surface reconnaissance, to identify permanent location for surface habitat.
Investigate surroundings visually with help of photographs/surface reconnaissance, to identify permanent location for greenhouse, laboratory, and sample storage modules.
Coordinate crew response to meteor penetration, hull breech, fire, ECLS, or other emergency.
Schedule tasks and monitor performance of work to ensure that opportunities and resources are allocated appropriately among crew personnel.

Coordinate surface habitat exercise device availability among crew to ensure access to maintain cardiovascular conditioning, muscle strength, and bone density.
Coordinate surface habitat simulator availability among crew to ensure refresher training for all required skills and functions.
Plan operations/timelines/work assignments (e.g., surface EVA, maintenance) using computer-based tools in consultation with MCC and onboard personnel.
Modify operations plans/timelines/work assignments in response to events using computer-based tools in consultation with MCC and onboard personnel.

Perform pre- and post-EVA inspection and planning tasks during Mars Surface Operations.

Conduct pre-EVA briefing/meeting with other crew and MCC personnel to plan EVA.
Conduct post-EVA briefing/meeting with other crew and MCC personnel to discuss previous EVA.
Conduct pre-EVA inspection/inventory of equipment, manually/visually, to ensure proper functioning.
Conduct post-EVA inspection/inventory of equipment, manually/visually, to ensure proper functioning.

Perform surface EVA physical functions on foot during Mars Surface Operations.

Carry incapacitated crew mate 20 meters to surface rover, manually while both are wearing surface EVA suits, to prepare for medical treatment.
Rise from prone position, using arms and legs while wearing surface EVA suit, to recover from fall on flat surface.
Rise from prone position, using arms and legs while wearing surface EVA suit, to recover from fall in loose regolith.
Bend over/stoop while wearing surface EVA suit to retrieve hand tool from planet surface.
Climb 3 meter ladder, manually while wearing surface EVA suit, to access Mars Surface Ascent Vehicle.
Adjust surface EVA suit controls, manually with gloved fingers, to operate mobile communications with Mars habitat personnel.
Adjust surface EVA suit controls, manually with gloved fingers, to optimize mobile life support system.
Adjust surface EVA suit controls, manually with gloved fingers, to operate mobile situation awareness data displays.
Carry harvested plant material from greenhouse to surface habitat galley, manually while wearing EVA suit, to prepare for crew consumption
Remove accumulated dust from greenhouse, manually using compressed gas canister while wearing surface EVA suit, to maintain optimal sunlight for plant growth.
Respond to puncture of surface EVA suit while wearing the suit on planetary surface, manually by retrieving and attaching temporary fast-patch.
Carry air filters from surface habitat air circulation system to planetary surface, manually while wearing surface EVA suit, to prepare for filter cleaning.
Blow accumulated dust from air filters, using portable compressed gas device while wearing surface EVA suit, to clean filter for reuse in habitat.
Measure surface distances using laser rangefinder while wearing surface EVA suit.
Inspect pre-positioned power-generation plant, visually/manually while wearing surface EVA suit, to verify proper functioning.

Monitor EVA systems during EVA during Mars Surface Operations.

Monitor surface EVA suit displays (e.g., time, radiation dosimeter, consumables), visually/cognitively, while wearing surface EVA suit to ensure safe operation.
Monitor surface EVA suit parameters (e.g., time, radiation dosimeter, consumables remaining), remotely from inside surface habitat, to ensure safe operation.
View display, visually while wearing surface EVA suit, to verify proper functioning of the Radiation Assessment Detector (RAD).
View display, visually while wearing surface EVA suit, to verify proper functioning of the weather monitoring station.
Monitor atmospheric sampling equipment, manually while wearing surface EVA suit, to ensure that data are recorded for later analysis and transmission to MCC.

Perform surface EVA communications functions during Mars Surface Operations.

Communicate with other crew members in the field, verbally while wearing surface EVA suit, to coordinate/advise actions.
Communicate with other crew members in the surface habitat, verbally while wearing surface EVA suit in the field, to coordinate/advise actions.

Perform surface EVA habitability functions during Mars Surface Operations.

Eat food while wearing surface EVA suit to enable uninterrupted operations on planetary surface.
Drink liquid while wearing surface EVA suit to enable uninterrupted operations on planetary surface.
Eliminate solid and liquid waste while wearing surface EVA suit, if necessary, to enable uninterrupted operations on planetary surface.

Inspect/prepare/ deploy surface rover during Mars Surface Operations.

Deploy surface rover vehicle, manually/visually while wearing surface EVA suit, to prepare for use.

Deploy surface rover trailer, manually/visually while wearing surface EVA suit, to prepare for use.

Inspect surface rover vehicle, manually/visually while wearing surface EVA suit, to verify functionality.

Inspect surface rover trailer, manually/visually while wearing surface EVA suit, to verify functionality.

Connect rover trailer to surface rover trailer hitch, manually while wearing surface EVA suit with the help of one other crew member, to prepare for use.

Connect umbilical from rover to surface EVA suit, manually while wearing EVA suit, to provide auxiliary life support.

Connect umbilical from rover to crew mate's surface EVA suit, manually while wearing EVA suit, to provide auxiliary life support.

Connect rover towing cable to surface rover trailer hitches, manually with the help of one other crew member while wearing surface EVA suit, to prepare for towing.

Load/unload surface rover/trailer for Mars Surface Operations.

Lift sample container, manually using Apollo-style block and tackle, to load container into Mars Surface Ascent Vehicle.

Remove food containers from pre-positioned lander and carry, manually while wearing surface EVA suit, to transfer provisions to surface habitat.

Retrieve nuclear power system/shield from storage/load onto rover trailer, manually using block/tackle while wearing surface EVA suit, for transporting to installation site.

Operate surface rover and trailer to a distance 1 km from habitat, manually while wearing surface EVA suit, to prepare for installing nuclear power reactor.

Remove nuclear power reactor and shield from rover trailer, manually using block/tackle while wearing surface EVA suit, to install system for power generation.

Retrieve power cable spool from storage/load onto rover trailer, manually while wearing surface EVA suit, to prepare for applying power to surface habitat.

Deploy power cable from rover trailer during traverse to reactor site, using spool device while wearing surface EVA suit, to switch from battery to external power source.

Retrieve inflatable structure from storage and load on rover trailer, manually, with two other crew members, while wearing surface EVA suit.

Retrieve well-drilling equipment from storage (pre-positioned) and attach to surface rover, manually while wearing surface EVA suit.

Retrieve H2O sublimation equipment from storage (pre-positioned) and attach to surface rover, manually while wearing surface EVA suit, to prepare for H2O extraction.

Perform surface rover maintenance functions during Mars Surface Operations.

Remove accumulated dust from surface rover windows, manually while wearing surface EVA suit, to maintain optimal visibility.

Conduct troubleshooting, manually/visually using schematics, procedures, and hand tools while wearing surface EVA suit, to identify fault in surface rover.

Remove/replace faulty component/connector manually/visually using hand tools and spare parts while wearing surface EVA suit to restore surface rover to operation.

Perform surface rover navigation functions during Mars Surface Operations.

Exit surface rover during pause in reconnaissance/traverse wearing surface EVA suit to perform navigation tasks.

Observe route markers/beacons, visually while operating surface rover and wearing surface EVA suit, to navigate route.

Review maps/charts/procedures, manually/visually, in surface rover to verify/alter/report route for surface sortie/traverse and geological research.

Operate surface rover navigation system to select/guide route during reconnaissance/traverse.

Operate surface rover (backup) dead-reckoning system to estimate position of rover on planetary surface.

Conduct preliminary reconnaissance of surroundings, visually, with one other crew member using rover vehicle.

Perform surface rover piloting/driving functions during Mars Surface Operations.

Operate surface rover vehicle on planetary surface, manually while wearing surface EVA suit.

Conduct expeditionary traverse of at least one Sol, with one other crew member using rover vehicle.

Perform surface rover operation functions during Mars Surface Operations.

Exit surface rover during pause in reconnaissance/traverse wearing surface EVA suit to perform geological tasks.

Enter Mars surface rover with one other crew member while wearing surface EVA suits to prepare for traverse.

Dig loose regolith from around surface rover wheel, manually using shovel while wearing surface EVA suit, to regain traction to proceed.

Deploy and attach battery cables to surface rover, manually while wearing surface EVA suit, to prepare for recharging rover batteries.
Deploy and attach battery cables from surface rover to habitat power connectors, manually while wearing surface EVA suit, to recharge rover batteries.
Move well-drilling rig to identified location, using surface rover while wearing surface EVA suit, to prepare for drilling H2O well.
Move H2O sublimation equipment to well location, using surface rover while wearing surface EVA suit, to prepare for H2O extraction
Operate surface rover with failed surface rover attached by towing cable to return failed rover to vicinity of Mars habitat for repair.

Perform construction-related EVA functions during Mars Surface Operations.

Pound stakes through habitat eyelets into planetary surface, manually using sliding hammer, to secure habitat to excavated foundation hole.
Pound stakes through sample storage module eyelets into planetary surface, manually using sliding hammer, to secure module to excavated foundation hole.
Retrieve solar panels/transformer from storage and carry to designated location near surface habitat, with two other crew members while wearing surface EVA suit.
Pound stakes through greenhouse module eyelets into planetary surface, manually using sliding hammer, to secure module to excavated foundation hole.
Connect pwr cables to connectors on power distribution bus/surface habitat, manually while wearing surface EVA suit, to switch from battery to external power source.
Activate controls, manually while wearing surface EVA suit, to switch from MEV/habitat battery to external power source.
Connect cables/plumbing from pre-positioned thermal control system to MEV/surface habitat, manually while wearing surface EVA suit, to enable heat radiation.
Activate controls, manually while wearing surface EVA suit, to initiate pre-positioned thermal control system.
Retrieve surface antenna, supports, and cables from storage and manually carry to designated location near habitat while wearing surface EVA suit.
Deploy surface antenna and attach cable connectors to antenna and habitat, manually with one other crew member while wearing surface EVA suits.
Adjust antenna, using hand tools and mobile data display while wearing surface EVA suit, to optimize communications between habitat and Earth stations.
Deploy and secure solar panels, manually using hand tools with two other crew members while wearing surface EVA suits.
Attach cables to solar panels, transformer, and surface habitat, manually with two other crew members while wearing surface EVA suit, to enable charging of batteries.
Adjust solar-tracking mechanism on solar panel system, manually while wearing surface EVA suit, to achieve optimal solar cell performance.
Attach cables to solar panels, transformer, and greenhouse, manually with two other crew members while wearing surface EVA suit, to provide power to greenhouse.
Retrieve Radiation Assessment Detector (RAD) from storage, manually while wearing surface EVA suit, and deploy in vicinity of surface habitat.
Connect power cable connectors from Radiation Assessment Detector (RAD) to power source, manually while wearing surface EVA suit, to activate system.
Retrieve weather monitoring equipment/station from storage, manually while wearing surface EVA suit, and carry to suitable location near surface habitat.
Connect power cable connectors from weather monitoring station to power source, manually while wearing surface EVA suit, to activate system.
Deploy inflatable structure, manually, with two other crew members, while wearing surface EVA suit.
Deploy surface atmosphere mining system manually with one other crew member, while wearing surface EVA suit, to begin O2/H extraction/storage.
Inspect vicinity of surface habitat, visually with the aid of photos and maps, to identify appropriate location to drill H2O well.
Install H2O sublimation system manually with one other crew member, while wearing surface EVA suit, to begin H2O extraction/storage.
Connect power cable connectors from H2O sublimation system to power source, manually while wearing surface EVA suit, with the help of one other crew member.
Remove accumulated dust from solar panels, manually while wearing surface EVA suit, to maintain optimal solar cell performance.

Perform construction-related EVA functions with heavy equipment during Mars Surface Operations.

Retrieve excavation equipment from storage (pre-positioned) and move to appropriate location, while wearing surface EVA suit, to prepare for digging habitat foundation.
Operate excavation equipment, while wearing surface EVA suit, to dig and level one meter hole the diameter/dimensions of surface habitat.
Move/deploy surface habitat into excavated hole, using rover and excavator while wearing surface EVA suit, to prepare habitat for occupancy.
Move regolith using excavator while wearing surface EVA suit to backfill around margins of the habitat base, to prepare habitat for occupancy.
Operate excavation equipment, while wearing surface EVA suit, to dig and level one meter hole the diameter/dimensions of sample storage module.
Move/deploy sample storage module into excavated hole, using rover and excavator while wearing surface EVA suit, to prepare module for receiving geologic samples.

Move regolith using excavator while wearing surface EVA suit to backfill around margins of the sample storage module base, to prepare for use.
Move excavation equipment to appropriate location, while wearing surface EVA suit, to prepare for digging greenhouse foundation.
Operate excavation equipment, while wearing surface EVA suit, to dig and level one meter hole the diameter/dimensions of greenhouse module.
Move/deploy greenhouse into excavated hole, using rover and excavator while wearing surface EVA suit, to prepare module for growing plants.
Move regolith using excavator while wearing surface EVA suit to backfill around margins of the greenhouse base, to prepare for use
Move excavation equipment to appropriate location, while wearing surface EVA suit, to prepare for digging sample storage foundation.

Perform maintenance/repair/monitoring functions during surface EVA operations during Mars Surface Operations.

Troubleshoot drill problems, visually/manually/cognitively while wearing surface EVA suit, to determine if equipment is repairable in the field.
Remove drill bit from drill pipe, manually using hand tolls while wearing surface EVA suit, to restore drill functionality
Remove auger bit from drill pipe, manually using hand tolls while wearing surface EVA suit, to restore drill functionality
Monitor temperature sensor remote display, visually, to verify successful deployment and recording of data.
Inspect surface atmosphere mining system visually/manually, while wearing surface EVA suit, to verify O2/H extraction and storage.
Inspect H2O sublimation system visually/manually, while wearing surface EVA suit, to verify H2O extraction/storage.
Inspect footing/base/structural components of surface habitat/greenhouse/module, visually, from outside the habitat while wearing surface EVA suit to ensure integrity.
Inspect fuel "cache" (fuel storage tanks), visually while wearing surface EVA suit, to verify that pre-positioned fuel production has been stored for later use.
Inspect hoses from fuel production plant to fuel storage tanks, visually while wearing surface EVA suit, to ensure there is no leakage.
Inspect fuel storage tanks, visually while wearing surface EVA suit, to ensure there is no leakage.
Inspect pre-positioned fuel production plant, visually/manually while wearing surface EVA suit, to verify proper functioning.

Perform science-related EVA functions during Mars Surface Operations.

Retrieve geological tools and equipment from storage and carry to surface rover/trailer, manually while wearing surface EVA suit, to prepare for reconnaissance.
Retrieve magnetometer from storage and carry to surface rover, manually while wearing surface EVA suit, to prepare for geological research.
Remove magnetometer from rover trailer and deploy, manually while wearing surface EVA suit, to prepare for recording magnetic data.
Retrieve gravitometer from storage and carry to surface rover, manually while wearing surface EVA suit, to prepare for geological research.
Remove gravitometer from rover trailer and deploy, manually while wearing surface EVA suit, to prepare for recording gravitational data.
Retrieve seismic testing munitions/equipment from storage and carry to surface rover, manually while wearing surface EVA suit, to prepare for geological research.
Remove seismic testing munitions/equipment from rover trailer and deploy, to prepare for recording seismic data.
Pound seismometers into rock, manually using slide hammer while wearing surface EVA suit, to deploy sensors.
Attach wire connectors to seismometer and to receiving terminal, manually wearing surface EVA suit, to prepare for recording seismographic data.
Retrieve cosmic radiation dosimeters from storage/deploy in vicinity surface habitat manually using digging tool while wearing surface EVA suit, to measure radiation.
Retrieve cosmic radiation dosimeters from storage/deploy in vicinity geological research manually using digging tool while wearing surface EVA suit, to measure radiation.
Remove cosmic radiation dosimeter from deployed site, manually while wearing surface EVA suit/carry to surface rover or habitat/laboratory for analysis/recording of data.
Retrieve weather balloon and portable hydrogen tank from storage and carry to surface rover, manually while wearing surface EVA suit, to prepare for geological survey.
Remove weather balloon and portable hydrogen tanks from rover trailer, fill balloon, attach remote sensors/transponders, and deploy balloon to conduct survey.
Remove rotary/percussion drill from rover, wearing surface EVA suit, and transport (10m) to drilling site with assistance of one other crew member.
Deploy temperature sensors (heat-flow probes) in drill hole manually, while wearing surface EVA suit.
Deploy route markers (3 meter stakes, flags/beacons) at intervals, manually using post-pounder and/or sledge while wearing surface EVA suit, to indicate route.
Retrieve non-rigid airship/ballonet, gondola, mast, portable hydrogen tank from storage, manually with two other crew members, while wearing surface EVA suit.
Deploy mooring mast with one other crew member, manually using hand tools and wearing surface EVA suit, to prepare for non-rigid airship/ballonet inflation.

Attach fitting to portable hydrogen tank/ballonet, fill ballonet with hydrogen, and attach gondola, manually with two other crew members, while wearing surface EVA suit.
Load supplies and equipment into ballonet gondola, manually with two other crew members, in preparation for aerial research/reconnaissance mission.
Operate magnetometer, manually while wearing surface EVA suit, to record magnetic data.
Operate gravitometer, manually while wearing surface EVA suit, to record gravitational data.
Operate seismic testing munitions/equipment, manually while wearing surface EVA suit, record seismic data.
Identify locations, visually in the field (i.e., rock) while wearing surface EVA suit, to deploy seismometers for seismological research.
Retrieve geological tools and equipment from surface rover/trailer, manually while wearing surface EVA suit, to prepare for geological research
Record field notes, verbally while wearing surface EVA suit, to preserve observations for later transcription.
Extract regolith core from drill and package core sample in plastic wrap, manually while wearing surface EVA suit, for later analysis.
Examine regolith core sample, visually while wearing surface EVA suit, to verify sample and conduct preliminary assessment.
Examine regolith core sample, using aseptic device/procedures while wearing surface EVA suit, to identify if sample contains biologic or toxic elements.
Extract sedimentary core from drill and package core sample in plastic wrap, manually while wearing surface EVA suit, for later analysis.
Examine sedimentary core sample, visually while wearing surface EVA suit, to verify sample and conduct preliminary assessment.
Examine sedimentary core sample, using aseptic device/procedures while wearing surface EVA suit, to identify if sample contains biologic or toxic elements.
Walk on planetary surface while carrying hand tools and wearing surface EVA suit to conduct geological research.
Climb crater wall while carrying hand tools and wearing surface EVA suit to conduct geological research.
Descend crater wall while carrying hand tools and wearing surface EVA suit to conduct geological research.
Descend gully while carrying hand tools and wearing surface EVA suit to conduct geological research.
Climb gully while carrying hand tools and wearing surface EVA suit to conduct geological research.
Scan immediate vicinity of planetary surface, visually through clear visor, to identify potential sites for geological research and collection (e.g., contrasting color).
Scan distant planetary surface, visually through clear visor, to identify potential sites for geological research and collection (e.g., contrasting color).
Scan surrounding planetary surface, visually through clear visor, to identify potential sites for geological research and collection (e.g., contrasting color).
Collect geological samples, manually using rock pick (i.e., geologist's hammer) and sample bags, while wearing surface EVA suit.
Collect geological samples, manually using Apollo-type rake (1m handle) and sample bags, while wearing surface EVA suit.
Collect geological samples, manually using Apollo-type scoop (1m handle) and sample bags, while wearing surface EVA suit.
Collect geological samples, manually using hand auger, while wearing surface EVA suit.
Label collection bags with location coordinates, manually with Sharpie-type marker while wearing surface EVA suit, to record origins of geological samples.
Insert rock/dust/regolith samples in labeled bag, while wearing surface EVA suit, for later analysis/storage/transport to Earth.
Insert labeled bags into curation collection bag, manually while wearing surface EVA suit, for transport to sample storage module.
Carry sample curation bag into sample storage module, manually while wearing surface EVA suit to preserve integrity of samples contained.
Record contents of curation bag in sample log, manually using dedicated keyboard while wearing surface EVA suit, to update inventory of samples collected
Dissect rock samples, manually while wearing surface EVA suit and using hand-held power cutting tool, to reveal smooth surface features/stratigraphy.
Operate camera to record still and video images of planetary surface/surroundings, while wearing surface EVA suit.
Operate camera to record still and video images of geological specimens/phenomena while wearing surface EVA suit.
Change lenses on camera while wearing surface EVA suit in the field.
Insert geologic samples in glove box, manually while wearing surface EVA suit, to prepare for aseptic analysis.
Inspect geologic samples, visually using hand-held magnifying tool/microscope while wearing surface EVA suit in the field, to conduct preliminary analysis.
Package geological samples, manually using aseptic equipment while wearing surface EVA suit, to prepare samples for safe return to Earth.

Remove and package ice core sample, manually while wearing surface EVA suit, for later analysis.
Enter ballonet gondola with one other crew member, manually while wearing surface EVA suit, to prepare for launch.
Launch and operate non-rigid airship/ballonet with one other crew member while wearing surface EVA suit to conduct aerial research/reconnaissance mission.
Recover non-rigid airship/ballonet with two other crew members while wearing surface EVA suit and attach lines to mooring mast after research/reconnaissance mission.

Perform science-related EVA functions with heavy equipment during Mars Surface Operations.

Retrieve high-vacuum pump/sampling equip from storage while wearing surface EVA suit/manually carry to vicinity of habitat to prepare for atmospheric sampling.
Deploy and operate high-vacuum pump and sampling equipment, manually while wearing surface EVA suit, to collect atmospheric data.
Operate rotary/percussion drill to depth of 10 meters with assistance of one other crew member while wearing surface EVA suit.
Add drill pipe section to stack, manually using hand tools while wearing surface EVA suit, to drill deeper.
Remove drill pipe section from stack, manually using hand tools while wearing surface EVA suit, to back drill/auger bit out of hole.
Position drill-bit and operate powered well-drilling equipment to drill approximately 10 meter hole to sub-surface water level.
Deploy and operate ice core drilling tool, manually while wearing surface EVA suit, to obtain ice core sample for analysis.

Perform geology-related science functions in surface habitat or modules during Mars Surface Operations.

Examine regolith core sample, visually in surface habitat/laboratory, to conduct assessment.
Examine sedimentary core sample, visually in surface habitat/laboratory, to conduct assessment.
Dissect rock samples, manually using hand-held power cutting tool in surface laboratory, to reveal smooth surface features/stratigraphy.
Evaluate geological data collected/analyzed, with aid of references and consultation, to plan further collection activities based on results.
Conduct astronomical observations, photography, and remote sensing in the surface habitat.
Analyze geological specimens and photographs, visually/cognitively, to develop hypotheses to guide additional field work.
Inspect geologic samples in glove box, manually/visually using hand tools/microscopes in surface laboratory, to perform aseptic analysis.
Inspect geologic samples, visually using magnifying tool/microscope in the surface habitat/laboratory, to conduct analysis/guide additional field research.
Inspect geologic samples, visually using binocular microscope in the surface habitat/laboratory, to conduct analysis/guide additional field research.
Inspect geologic samples, visually using spectrometer in the surface habitat/laboratory, to conduct analysis/guide additional field research.
Inspect ice core samples, visually using spectrometer in the surface habitat/laboratory, to conduct analysis/guide additional field research.

Perform human research-related science functions in surface habitat or modules during Mars Surface Operations.

Complete mood inventory questionnaires for later transmission to TSC for analysis.
Collect saliva samples, label, and preserve, manually, for later analysis.
Collect blood samples, label, and preserve, manually, for later analysis.
Record confidential audio/visual journal entries for later transmission to TSC for analysis and archiving.
Conduct life science experiments involving crew members, manually using various instruments in the surface habitat, to generate data.
Record/report results of life science investigations/procedures, manually using keyboard, to document activity.
Compose/record electronic/video journal, using keyboard/computer in surface habitat/laboratory, to create/preserve personal account of experiences.

Perform administrative/planning-related science functions in surface habitat or modules during Mars Surface Operations.

Identify locations visually from photographs and charts in the surface habitat to deploy seismometers for seismological research.
Transcribe audio field notes, using keyboard in surface habitat/laboratory, for later review/analysis/traverse route-planning.
Compose/update log of samples, using keyboard in surface habitat/laboratory, to create inventory of material collected to date.
Compose report concerning geological research, using keyboard in surface habitat/laboratory, to document activity/results.
Annotate aerial photograph, manually on computer indicating habitat, antennae, equipment, etc., to create interactive map of Mars base for planning and safety.

Perform biology-related science functions in surface habitat or modules during Mars Surface Operations.

Record digital image of geologic/biologic sample, manually using binocular microscope camera, for later reference/analysis.

Place geologic sample, manually, in the sample analysis module (i.e., "Easy Bake Oven") in the surface habitat/laboratory to prepare for analyzing sample.

Operate sample analysis module in the surface habitat/laboratory, manually, to test for presence of hydrogen, oxygen, and nitrogen (associated with life).

Inspect Martian water samples, visually using binocular microscope in the surface habitat/laboratory, to conduct analysis/guide additional field research.

Inspect Martian water samples, visually using spectrometer in the surface habitat/laboratory, to conduct analysis to guide additional field research.

Conduct culturing experiment, manually in laboratory module while wearing protective garments, to test sample material for biological content.

Conduct wet chemistry experiment, manually in laboratory module while wearing protective garments, to test sample material for biological content.

Conduct RNA sequencing experiment, manually in laboratory module while wearing protective garments, to test sample material for biological content.

Perform robot operations-related functions during Mars Surface Operations.

Deploy and operate robot, remotely on planetary surface, to inspect external features of habitat and external equipment/structures.

Operate rover, remotely on surface, to explore in vicinity of habitat.

Operate rover, remotely on surface, to explore areas in vicinity of field camp.

Operate robot, remotely on surface, to assemble/construct/ system elements to prepare field camp for humans.

Operate robot, remotely on surface, to deploy/position offloaded system elements to prepare field camp for humans.

Deploy and operate robot, remotely on surface, to explore possible sites for field camp to extend EVA range.

Deploy and operate robot, remotely on surface, to deliver/offload assets/equipment/materials to prepare field camp for humans.

Retrieve geological samples from robot, manually, and place in surface laboratory/storage facility for later analysis/transport to Earth.

Deploy and operate robot, remotely on planetary surface, to repair/maintain external equipment/structures (e.g., to blow dust from solar panels).

Deploy and operate robot, remotely on surface, to clean up potentially contaminating fluid spill on Mars surface (e.g., propellant, ammonia, human waste).

Deploy and operate robot, remotely on surface, to reconnoiter route/site for future traverse/research.

Deploy and operate robot, remotely on surface, to collect, bag, and return geological samples to surface habitat/laboratory.

Deploy and operate robot, remotely on surface, to test geological samples for biologic/toxic elements.

Perform robot maintenance-related functions during Mars Surface Operations.

Retrieve robot from storage, manually while wearing surface EVA suit, to prepare for use.

Troubleshoot robot problems, visually/manually/cognitively while wearing surface EVA suit, to determine if equipment is repairable in the field.

Inspect robot, visually/manually while wearing surface EVA suit, to prepare for use.

Identify and replace components (line replaceable units, wheels, etc.), manually per procedures, in surface habitat/laboratory to restore surface robot functionality.

Inspect hoses from fuel production plant to fuel storage tanks, remotely using surface robot vehicle, to ensure there is no leakage.

Inspect fuel storage tanks, remotely using surface robot vehicle, to ensure there is no leakage.

Inspect pre-positioned fuel production plant, remotely using surface robot vehicle, to verify proper functioning.

Respond to dental emergencies during Mars Surface Operations.

Conduct dental examination on crew member, manually/visually, to investigate complaint of tooth/jaw pain.

Interpret results of dental examination, cognitively with MCC consultation, to identify source of apparent tooth/jaw pain.

Apply temporary tooth filling and smooth excess (instruct patient to limit solid food consumption on affected side of mouth for 12-24 hours) to repair dental filling.

Prepare dental adhesive, fit, apply adhesive, and replace crown.

Administer pain medicine (Eugenol), manually as needed, to treat a crewmember's fractured tooth showing exposed pulp.

Apply direct pressure and hold until bleeding stops to treat loss of tooth of a crewmember.

Administer medication and if pain severe perform dental nerve block to treat crewmember's dental pain.

Perform medical diagnoses and evaluations, cognitively, during Mars Surface Operations.

Diagnose medical condition, cognitively and verbally through interviews with conscious ill or injured crewmember and physical exam.

Evaluate unresolved sleep disorder, cognitively per procedures, to diagnose problem and identify treatment/intervention.

Perform tests and examinations, physically, to support medical diagnoses during Mars Surface Operations.

Apply hand-held ultra-sonic device to naked crew member skin, manually using gel, to obtain image of internal organs/bones for diagnosis.

View ultra-sonic display, visually while manipulating hand-held device manually, and interpret results of ultra-sonic imaging test.

Use medical software along with vitals/test results to help diagnosis condition of conscious or unconscious injured/ill crewmember.

Operate hand-held ultra-sonic device, manually while visually inspecting display, to assess/measure bone demineralization of crew member.

Record/report results of ultra-sonic investigations/procedures, manually using keyboard, to document activity.

Conduct physical/cognitive tests in surface habitat/laboratory to assess fitness for duty (automatically-scheduled/results transmitted to Earth).

Collect vitals from injured/ill crew (e.g. temp, pulse, oxygen saturation, respiration rate, blood pressure) with tools in kit, reassess as treatments/meds are administered.

Perform decompression sickness examination with the aid of an electronic form to determine if treatment is needed.

Collect Electrocardiogram (ECG) wave properties data with ECG hardware and leads placed on the patient for analysis of heart rate and variability.

Perform initial evaluation/treatment of chest pain by administering Aspirin/delivering oxygen with respiratory equip/collecting vitals and ECG, and listening to lung sounds.

Measure pulse and respiratory rate, administer oxygen and inhaled Albuterol, perform chest exam, and obtain blood pressure to treat difficulty breathing.

Obtain vital signs and photo-document rash, injury or other ailments to perform periodic health evaluation of a crewmember.

Examine eye using a Panoptic tool to test near and far visual acuity, visual field, contrast sensitivity, and potential cornea abrasions.

Apply blood pressure device and monitor to assess patient's blood pressure.

Collect sample via swab and perform culture, manually, to test for bacterial infection.

Take image of the back of the eye, manually using a retinal camera (fundus exam), to test for visual impairment and/or increased intracranial pressure (VIIP).

Examine patient, manually/cognitively, to diagnose lower extremity stress fracture; proscribe reducing weight-bearing activities for up to 12 weeks.

Examine skin, visually, to detect evidence of radiation-induced skin cancer.

Examine stool samples, visually using microscope, to detect evidence of radiation-induced cancer.

Collect samples of blood/urine/saliva, manually, to prepare for lab tests.

Conduct lab tests (e.g., CBC, chemical panels, strep throat), manually on collected samples, to help diagnose medical problem.

Respond to medical emergencies, following procedures and with equipment provided, during Mars Surface Operations.

Clear airway obstruction of choking conscious crewmember by performing abdominal thrusts with fist below ribcage pulling sharply inward and upward until object clears.

Treat patient who becomes unconscious from choking by attempting to clear foreign object manually/ pinch nose/apply breaths and begin CPR.

Perform CPR on unconscious /not breathing crewmember and determine if additional actions are needed as apart of Advanced Cardiac Life support.

Perform defibrillation on unconscious electrically isolated crewmember using AED to restore heartbeat.

Irrigate eye and perform eye exam to treat chemical exposure to a crewmember's eye.

Minimize eye and skin exposure to toxics to prepare for treating exposed crewmate.

Remove exposed crewmates soiled clothes, particles/liquid and irrigate with water (flush eye with water) for respiratory exposure follow Difficulty breathing procedure.

Check for capillary refill and pulses below injury location, apply splint, secure with ACE bandage to treat injured extremity (e.g., leg, arm).

Insert catheter into pleural space between lung/chest wall, producing a pathway for air to escape to perform a needle decompression of a pneumothorax (collapsed lung).

Secure Airway/Breathing/Circulation (ABCs)/perform physiological monitoring (e.g., Vitals and Chem Labs), manually and cognitively, to manage acute radiation syndrome.

Administer epinephrine, oxygen, IV antihistamines and cortisone, and beta-agonist (e.g., Albuterol), manually, to treat anaphylaxis.

Apply physical force and binding/duct tape, manually with the help of another crew member, to restrain a crewmember experiencing a behavioral emergency.
Secure crewmember to a flat surface, manually using restraints, to immobilize for treatment of suspected spinal cord trauma.
Administer anti-inflammatory drugs, manually, to immobilized crewmember to treat spinal cord trauma.
Perform surgery, manually using available instruments, to repair a detached retina.
Apply cast, splint, or brace to extremity (e.g., arm, leg), manually, to immobilize simple fracture.
Perform surgery, manually using available instruments, to repair a compound fracture of arm or leg bone.
Perform surgery, manually using available instruments, to treat acute appendicitis.

Administer medications during Mars Surface Operations.

Administer medication to suppress seizure/avoid loss of consciousness and uncontrolled muscle contractions.
Administer intramuscular shot, take vitals, and administer oxygen as needed to protect patient from injury from seizure.
Administer meds (e.g., antibiotics, antidiarrheal, antihistamine, decongestants, lubricants, pain relievers, sleep, steroids, stimulants and stool softeners) for conditions.
Administer hydrocodone and acetaminophen (Vicodin HP) and notify CMO to treat pain.
Administer medications or an intramuscular shot (e.g. Epipen) to treat an allergic reaction.
Apply ointment, bandages, and latex barrier gloves to hands to treat blisters from surface EVA work.
Apply ointment, bandages, and latex barrier covering to feet to treat blisters from surface EVA work.
Apply ointment and bandages to pressure points on body to treat abrasions from surface EVA work.
Apply a thin layer of Mupirocin (Bactroban) ointment and bandage affected areas to treat burned skin.
Deliver meds to lungs with inhaler by patient closing lips around the inhaler, inhaling slowly, holding breath for 10 seconds and removing inhaler from mouth and exhaling.
Attach prepared fluid set to an inserted IV catheter to administer IV fluids and medications.
Apply medical drops into the ear canal to treat ear pain caused by blockage (i.e., Barotrauma) that is not alleviated by yawning or chewing.
Administer antibiotics, manually per instructions, to treat ear infection.
Administer antibiotic ointments/drops, manually per instructions, to treat eye irritations/abrasions/infections.
Administer appropriate antibiotic (oral or IV) to treat confirmed bacterial infection.
Administer pill (TBD) to treat acute radiation syndrome.
Administer sedative, manually via syringe, to treat crewmember experiencing a behavioral emergency.
Administer IV antibiotics, manually, to treat sepsis (administer vasopressor medication if blood pressure remains low).

Perform medical treatments during Mars Surface Operations.

Insert catheter in the bladder to drain urine (self-catheterize) for urine retention.
Operate hand-held ultra-sonic device, manually while visually inspecting display, to locate and then disintegrate renal stone in crew member.
Place PHA QDM on ill crew/deliver oxygen for 2 hours, hydrate 1 liter per hour for 2 hours (administer IV fluids if unable to drink) to treat decompression sickness.
Administer traction and counter-traction until finger slips back in place to relocate a dislocated finger.
Administer traction and counter-traction until shoulder slips back in place to relocate a dislocated shoulder
Insert staples, sutures, or Derma bond depending on type and location of cut to repair skin laceration.
Administer Lidocaine or Epinephrine with a syringed needle, then create opening with scalpel to drain, to treat skin or dental abscess.
Remove staples using a skin staple remover to complete repair.
Remove sutures with medical scissors to complete repair.
Insert Oral Airway device halfway into mouth and rotate 180 degrees before inserting until it is flush against the lips to aid ventilation of unconscious patient.
Place Ambu Bag mask over nose and mouth and gently squeeze bag to deliver breaths every 5 to 8 seconds to assist temporary ventilation of a compromised patient.

Deliver oxygen to a respiratory distressed patient by automated ventilation provided in a respiratory support pack.
Insert an IV catheter and secure with medical tape to provide intravenous access for medications and fluids.
Pinch fleshy part of nose, manually, for 10 minutes to stop nose bleeding.
Insert nasal packing and drops, manually per instructions, to stop persistent nose bleeding.
Remove wax from ear, manually using curette/medical drops, to treat ear pain.
Clean fingernail, apply antibiotic ointment, cover with adhesive bandage, manually until a new nail grows, to treat/protect fingernail damage from EVA.
Apply ice (multiple sessions) and administer pain medication as needed, manually, to treat back/shoulder/neck sprain/strain.
Apply ice/cold pack and compress with bandage, manually, to treat wrist, elbow, ankle, or knee sprain/strain.
Apply splint, manually, to treat unresolved wrist, elbow, ankle, or knee sprain/strain.
Drain sinus passageway (with nasal spray) and administer antibiotics, manually, to treat acute sinusitis.
Perform a reduction maneuver gently and slowly, manually with the assistance on another crewmember, to realign a dislocated elbow.

Monitor crew behavioral health/respond to behavioral health issues during Mars Surface Operations.

Monitor individual behavioral health by speaking with each crew member with the goal of identifying symptoms of maladjustment.
Implement countermeasures (e.g., counseling, software) if symptoms of maladjustment or degraded behavioral health are detected among crew personnel.

Perform greenhouse/plant growth-related functions in surface module during Mars Surface Operations.

Adjust growing medium mixture, manually to augment automated system, manually via keyboard, when necessary to optimize plant growth.
Adjust/move plant containers/plumbing/reflectors, manually while wearing protective gloves, when necessary to optimize plant growth.
Remove plant material, manually using hand tools while wearing protective gloves, to harvest plants/vegetables for crew consumption.
Monitor plant growth, remotely via video feed to surface habitat, to verify/measure proper functioning of greenhouse.
Monitor plant growth, visually in person, to verify/measure proper functioning of greenhouse.

Perform maintenance/repair functions in surface habitat or modules during Mars Surface Operations.

Repair tear/puncture in surface EVA suit by manually turning suit inside out, cleaning fabric with alcohol, applying adhesive and patch, clamping firmly/allowing to dry.
Modify surface EVA suit, manually in surface habitat/laboratory, to adjust length of torso segment in response to spine elongation in reduced gravity.
Troubleshoot surface EVA suit, manually in surface habitat/laboratory, to identify problem.
Remove/replace component, manually in surface habitat/laboratory, to repair surface EVA suit.
Repair tear/puncture of surface habitat/module, manually by cleaning fabric, scoring surface with tool, applying adhesive/patch, clamping firmly, allowing to dry.
Repair broken hand tool, manually in surface habitat, using repair kit/materials, to restore functionality for later use.
Review schematics and other documentation, visually, to isolate plumbing (e.g., cooling, CLSS) fault in space craft.
Review schematics and other documentation, visually, to isolate plumbing (e.g., cooling, CLSS) fault in surface habitat or equipment.
Inspect plumbing (e.g., cooling, CLSS), visually and with hand tools, to identify source of plumbing fault in surface habitat or equipment.
Remove and replace plumbing component (e.g., section, valve), using hand tools and schematics, to restore system functionality in surface habitat or equipment.
Retrieve spare parts/materials (e.g., valve, duct tape) from storage/move to work site on surface, manually while wearing surface EVA suit, for troubleshooting/repair.
Remove 1 meter of duct tape from roll on rover, manually while wearing surface EVA suit, to temporarily repair leaking hydraulic hose/fitting.
Wrap 1 meter of duct tape around hydraulic hose/fitting on rover (or other equipment), manually while wearing surface EVA suit, to temporarily repair leak.
Retrieve spare parts/materials (e.g., valve, duct tape) from storage and move to work site in surface habitat, manually, to prepare for troubleshooting/repair.
Cut pipe, manually while wearing surface EVA suit and using hand saw, to remove damaged section of space habitat/equipment plumbing.
Insert section of pipe and attach in place, manually while wearing surface EVA suit and using electric soldering tool, flux, and solder to repair habitat/equipment plumbing.
Remove/replace filters in surface habitat, manually, to ensure safe removal of dust from breathable air.

Perform electronics/computers maintenance/repair functions in surface habitat or modules during Mars Surface Operations.

Review schematics and other documentation, visually, to isolate electronic fault in surface habitat or equipment.

Insert test equipment probes in electronic components, manually, and observe displays, visually, to isolate electronic fault in surface habitat or equipment.

Inspect circuit board, visually, to identify short circuit or loose/missing connection in surface habitat or equipment.

Inspect circuit board, visually, to identify scorching that might indicate degraded/faulty/failed electronic component in surface habitat or equipment.

Inspect circuit board, visually, while wearing surface EVA suit to help isolate source of electronic equipment trouble in the field.

Review documentation/enter control inputs, visually/manually, to diagnose software problem.

Enter control inputs, manually, to load software patch/reload software.

Replace electronic connector on wire/cable in surface habitat, manually, using hand tools and spare parts.

Replace electronic connector on wire/cable, manually while wearing surface EVA suit, using hand tools and spare parts.

Perform emergency functions in surface habitat or modules during Mars Surface Operations.

Respond to puncture of surface habitat/greenhouse/module, manually by retrieving and attaching temporary fast-patch.

Retrieve and don protective fire-fighting ensemble, manually, to prepare for fire emergency in surface habitat or module.

Remove fire extinguisher from bracket in surface habitat or module and manually carry to source of fire.

Point fire extinguisher nozzle at burning material and activate system manually while wearing protective ensemble to suppress fire.

Retreat to shielded area of surface habitat with other members of the crew in response to critical radiation event warning.

Remain in shielded area of surface habitat with other members of the crew during critical radiation event.

Perform 3D printer-related functions in surface habitat or modules during Mars Surface Operations.

Program 3-D printer, manually via computer inputs, to fabricate a replacement part for a mechanical system on planet surface.

Operate 3-D printer, manually via computer inputs, to fabricate a replacement part for a mechanical system on planet surface.

Remove and trim object fabricated by 3-D printer, manually using hand tools, to prepare replacement part for a mechanical system on planet surface.

Disassemble 3-D printer, manually using hand tools, to perform routine maintenance/cleaning.

Disassemble 3-D printer, manually using hand tools, to diagnose fault/restore functionality.

Perform monitoring functions in surface habitat or modules to ensure crew and system health during Mars Surface Operations.

Monitor display, visually from inside surface habitat, to verify proper functioning of the Radiation Assessment Detector (RAD).

Monitor display, visually from inside the surface habitat, to verify proper functioning of the weather monitoring station.

Monitor remote-sensing systems, visually from inside the surface habitat, to learn of impending surface weather event (i.e., dust storms).

Monitor atmospheric sampling equipment, remotely from surface habitat, to ensure that data are recorded for later analysis and transmission to MCC.

Monitor balloon sensors/transponders, remotely from surface habitat, to ensure that data are recorded for later review and transmission to MCC.

Monitor radiation-detection systems, visually/aurally, for evidence of Solar Proton and Galactic Cosmic Ray Events (SPE/GCR).

Monitor system displays, visually, to verify normal functioning of power-generation system.

Monitor system displays, visually, to verify normal functioning of *surface habitat life support system*.

Monitor system displays, visually, to verify normal functioning of *telemetry system*.

Monitor system displays, visually, to verify normal functioning of surface habitat *communication system*.

Monitor habitat atmosphere, visually/manually, by checking displays and comparing values to reference documents.

Inspect the footing/base and structural components of the surface habitat/greenhouse/module, visually, from inside the habitat to ensure integrity.

Adjust controls in surface habitat or modules to ensure proper functioning of systems during Mars Surface Operations.

Adjust controls, manually per procedures, to maintain normal functioning of power-generation system.

Adjust controls, manually per procedures, to maintain normal functioning of surface habitat *life support system*.

Adjust controls, manually per procedures, to maintain normal functioning of *telemetry system*.

Adjust controls, manually per procedures, to maintain normal functioning of surface habitat *communication system*.

Adjust controls, manually per procedures, to maintain optimum habitat atmosphere (temperature, CO2, etc.).

Perform training and skill refreshment in surface habitat during Mars Surface Operations.

Review procedures for emergency mission abort on planetary surface to refresh training.

Review emergency procedures for contingencies (fire, micro-meteorite impact, hull breech, outgassing, ECLS failure, etc.) while on surface to refresh training.

Configure surface habitat computer to support training simulation and task preparation.

Conduct (training) simulation using surface habitat computer to refresh piloting skills for Mars Surface Ascent.

Conduct (training) simulation using surface habitat computer to refresh navigation skills for Mars Surface Ascent.

Conduct (training) simulation using surface habitat computer to refresh communication skills for Mars Surface Ascent.

Read procedures and technical information to prepare for conducting tasks during Mars Surface Ascent.

Conduct final preparation/training tasks to prepare for Mars Surface Ascent.

Prepare for Mars Surface Ascent during Mars Surface Operations.

Connect hose to fittings on fuel storage tanks and Mars Excursion Vehicle (MEV)/Mars Ascent Vehicle (MAV), manually while wearing surface EVA suit, for refueling.

Activate pumps on fuel production system, manually via keyboard input from habitat, to transfer fuel from storage tanks to MEV/MAV.

Enter Mars Excursion Vehicle (MEV)/Mars Ascent Vehicle (MAV), physically while wearing pressure suit, to prepare for launch (Mars Surface Ascent maneuver).

PHASE 8: MARS SURFACE ASCENT

The eighth phase of the mission begins when the crew enters the Mars Ascent Vehicle (MAV) to prepare for launching from the surface of Mars to rendezvous with the interplanetary ship in Mars orbit. Assume approximately 14 hours from ingress to the MAV and shutdown of MAV systems after docking with the interplanetary ship in Mars orbit. A “missed attempt” for rendezvous would add 24 hours to the duration of this mission phase.

Conduct communications checks and communicate observations/evaluations to other crew and MCC personnel, verbally using communications system.

Receive final thrust and duration information from MCC to prepare for Mars Surface Ascent maneuver.

Communicate status of systems during Mars Surface Ascent maneuver in heavy buffeting to depart surface for Mars Orbit.

Communicate system status, verbally to crew members using internal communications equipment, during controlled ascent.

Communicate system status, verbally to MCC using external communications equipment, during controlled ascent.

Communicate successful docking with space craft in Mars Orbit, verbally and via text, to MCC using external communications equipment to confirm status.

Communicate systems shut down and safing to crew via internal communication system to advise of status.

Communicate systems shut down and safing to MCC via external communication systems to advise of status.

Prepare for Mars Surface Ascent maneuver.

Inspect Mars Excursion Vehicle (MEV)/Mars Ascent Vehicle (MAV) to verify that systems are go for ascent maneuver.

Don pressure suit, manually with the help of one other crew member, in preparation for Mars Surface Ascent maneuver.

Enter control inputs, manually, to convert Mars Excursion Vehicle (MEV)/Mars Ascent Vehicle (MAV) from surface mode to ascent mode.

Stow and secure all equipment, manually per load plan, to prepare Mars Excursion Vehicle (MEM)/Mars Ascent Vehicle (MAV) for Mars Surface Ascent maneuver.

Attach to individual crew maneuver position, while wearing pressure suit, in preparation for Mars Surface Ascent maneuver.

Monitor systems and perform piloting functions during Mars Surface Ascent.

Enter control inputs, manually, to configure Mars Excursion Vehicle computers for Mars Surface Ascent maneuver.

Enter control inputs, manually wearing pressure suit/gloves, to override auto firing of MEM/MAV main engine if automated system fails.

Enter control inputs, manually wearing pressure suit/gloves, to override automatic systems in response to system displays, if necessary.
Enter main engine control inputs, manually wearing pressure suit/gloves during buffeted ascent, to maneuver MEV to location near space craft in Mars Orbit.
Enter control inputs, manually wearing pressure suit/gloves, to shut down MEM/MAV main engine near space craft in Mars Orbit.
Adjust attitude control thrusters, manually wearing pressure suit/gloves, to dock Mars Excursion Vehicle MEM/MAV to space craft in Mars Orbit.
Adjust attitude control thrusters, manually wearing pressure suit/gloves, to maneuver MEM/MAV to space craft in Mars Orbit.
Adjust controls, manually wearing pressure suit/gloves, to shut down attitude control thrusters and other systems after docking with space craft in Mars Orbit.
Enter control inputs, manually, to activate engine shut down if displays indicate failure of automated shut down, to ensure safing of Mars Ascent Vehicle after docking.
Activate docking system shut down manually by control inputs if displays indicate failure of automated shut down, to ensure safing of MAV after docking.
Monitor automatic firing of Mars Excursion Vehicle (MEM)/Mars Ascent Vehicle (MAV) main engine, visually, for Mars Surface Ascent maneuver.
Monitor displays during Mars Surface Ascent maneuver, visually in heavy buffeting wearing pressure suit, to depart surface for Mars Orbit.
Monitor system displays, visually in heavy buffeting wearing pressure suit, to verify correct functionality at appropriate times during ascent to Mars Orbit.
Monitor system displays, visually wearing pressure suit, to assess proximity and verify docking with space craft in Mars Orbit.

Perform post-Mars Ascent maneuver functions.

Enter control inputs, manually wearing pressure suit/gloves, to secure (other) flight systems after engine shut down to ensure safing of MAV after docking.
Verify automated engine shut down by visually monitoring displays to ensure safing of Mars Ascent Vehicle after docking.
Verify automated docking system shut down by visually monitoring displays to ensure safing of Mars Ascent Vehicle after docking.

PHASE 9: TRANS-EARTH INJECTION

The ninth phase of the mission begins with the crew preparing the interplanetary ship for the journey home and ends approximately six days later after a main engine burn of 60 minutes has propelled the ship on a course to intercept Earth.

Conduct communications checks and communicate observations/evaluations to MCC personnel, verbally using communications system.

Receive final thrust and duration information from MCC to prepare for initiating Trans-Earth Injection (TEI).

Take position and prepare vehicle, manually while wearing pressure suit and helmet, to prepare for launch from Mars Orbit.

Don pressure suit, manually with the help of one other crew member, in preparation for thrust maneuver to achieve Trans-Earth Injection.
Transfer equipment and samples, manually, from Mars Excursion Vehicle (MEV)/Mars Ascent Vehicle (MAV) to space craft, in preparation for TEI.
Stow and secure all equipment, manually per load plan, to prepare space craft for thrust maneuver to achieve Trans-Earth Injection.
Stow and secure all samples collected on the surface, manually per load plan, to prepare space craft for thrust maneuver to achieve Trans-Earth Injection.
Attach to individual crew maneuver position, while wearing pressure suit, in preparation for thrust maneuver to achieve Trans-Earth Injection.

Monitor systems and perform piloting functions during Trans Earth Injection.

Enter control inputs to configure space craft computers in preparation for thrust maneuver to achieve Trans-Earth Injection.
Enter control inputs to override automatic firing of main engine for thrust maneuver to achieve Trans-Earth Injection, if necessary.
Monitor automatic firing of main engine, visually, for thrust maneuver to achieve Trans-Earth Injection.
Monitor displays and communicate status of systems during thrust maneuver in heavy buffeting to achieve Trans-Earth Injection.

PHASE 10: CRUISE TO EARTH

The tenth phase of the mission is the unpowered cruise to Earth, which will take approximately 180 days (i.e., six months). The crew will perform refresher training using onboard computer simulations to prepare for the final phases of the mission; however, most of the crew's time will be devoted to exercise and to science tasks to provide meaningful work during the cruise.

Conduct communications checks and communicate observations/evaluations to other crew and MCC personnel, verbally using communications system during Cruise to Earth.

Operate communications system, manually, to receive transmission from MCC.
Operate communications system, manually, to transmit message to MCC.
Speak with other members of the crew concerning technical and task-related topics.
Speak with other members of the crew concerning non-technical and non-task-related topics.
Perform interviews and Public Affairs Office (PAO) events, using communications system, to inform Earth public of progress.
Transmit data collected during the Transit of Earth to ground stations immediately following event.
Interact with crew mates, personally, concerning task performance.
Interact with crew mates, personally, concerning non-task-related matters.
Compose/record electronic/video journal, using keyboard/computer in space craft, to create/preserve personal account of experiences.
Conduct physical/cognitive tests in space craft to assess fitness for duty (automatically-scheduled/results transmitted to Earth).

Conduct EVA to perform maintenance or retrieve items from outside the interplanetary space vehicle during Cruise to Earth.

Don pressure suit in response to meteor penetration or hull breech alarm, manually, with crew members helping each other.
Conduct EVA for maintenance or to retrieve needed supplies/equipment/expertise.
Remove and stow pressure suit following departure burn (i.e., Trans-Earth Injection).

Use interplanetary space vehicle waste management systems for liquid/solid waste (i.e., toilet/bodily function) during Cruise to Earth.

Use space craft waste management system for liquid waste (i.e., toilet/bodily function).
Use space craft waste management system for solid waste (i.e., toilet/bodily function).

Use interplanetary space vehicle hygiene systems for cleaning during Cruise to Earth.

Activate hygiene system to enable hand and body washing.
Shave face, manually using safety razor/soap/water, to remove beard growth.
Shave face, manually using electric razor, to remove beard growth.
Cut hair, manually using clippers/scissors/comb/vacuum tube, to remove excess hair growth.
Operate hygiene system to clean/disinfect hands and body.
Operate hygiene system to clean/brush teeth.
Retrieve wet wipes, towel, and clothing to clean body after exercise in preparation for study and work-related tasks.
Remove personal garments from storage in preparation for changing clothes.
Doff (remove) soiled garments and don clean clothing.
Insert soiled garments in collection container to dispose.

Maintain space craft waste management systems during Cruise to Earth.

Remove and replace bio collection container from waste management system, manually, to ensure continuity of operation.
Discard packaging waste in trash compactor, manually, to clear galley.
Operate trash compactor, manually, to increase space for additional packaging waste.
Remove compacted packaging waste from trash compactor, manually, and transport to onboard storage.
Insert new sanitary liner in trash compactor, manually, to prepare for additional use.

Prepare/eat meal, manually, using interplanetary space vehicle food hydration/heating equipment/galley during cruise to Earth.

Transfer food packages from deep storage to proximal storage, manually, to prepare galley for crew use.
Activate food hydration/heating equipment, manually, to prepare galley for crew use.
Prepare meal for crew consumption, manually, using space craft food hydration/heating equipment.

Eat meal together with other members of the crew in the space craft ward room/galley.

Conduct recreational activities, individually and as a crew, during Cruise to Earth.

Read articles, books, etc., during leisure periods for recreation.

Listen to music individually during leisure periods for recreation.

Listen to music individually while exercising for recreation.

Watch video (movies, TV programs, documentaries, etc.) individually while exercising for recreation.

Watch video (movies, TV programs, documentaries, etc.) individually during leisure periods for recreation.

Watch video (movies, TV programs, documentaries, etc.) together with other crew members during leisure periods for recreation.

Play chess and other board games together with other crew members during leisure periods for recreation.

Play chess with MCC personnel and others on Earth during leisure periods for recreation.

Sleep during cruise phase for approximately eight hours each 24-hour period, during Cruise to Earth.

Retrieve sleeping bag from storage and attach bag to bulkhead davits to prepare for sleep period.

Enter secured sleeping bag and begin sleep period to restore cognitive/physical functioning.

Conduct inventories and update records during Cruise to Earth.

Conduct and maintain inventories of consumable supplies, visually/manually (e.g., food, water, O2), to update records.

Conduct and maintain inventories of spare parts and materials, visually/manually, to update records.

Exercise daily using onboard equipment during Cruise to Earth.

Configure resistive device and perform exercise to maintain cardiovascular conditioning, muscle strength, and bone density.

Mount bicycle ergometer and perform exercise to maintain cardiovascular conditioning, muscle strength, and bone density.

Don harnesses and perform exercise using treadmill to maintain cardiovascular conditioning, muscle strength, and bone density.

Assess displayed and aural information, cognitively, to determine appropriate course of action during Cruise to Earth.

Identify Emergency Alarm (i.e., Loss of pressure, Fire, Toxic substance/emission) and develop repair/recovery plan.

Identify Caution/Warning Alarm (e.g., CO2, ECLS, Navigation) and develop repair/recovery plan.

Respond to technical emergencies, following procedures and with equipment provided, during Cruise to Earth.

Retreat to shielded area of space craft with other members of the crew in response to critical radiation event warning.

Remain in shielded area of space craft with other members of the crew during critical radiation event.

Respond to space craft fire alarm.

Respond to space craft micro-meteorite impact alarm.

Identify precise location of meteor penetration/hull breech, visually/aurally, assess severity, and determine method(s) to stop loss of pressure.

Retrieve repair kit from storage and carry to location of meteor penetration or hull breech.

Apply patch and adhesive material to meteor penetration site, manually, to close leak.

Retrieve and don protective fire-fighting ensemble, manually, to prepare for fire emergency.

Remove fire extinguisher from bulkhead bracket and manually carry to source of fire.

Point fire extinguisher nozzle at burning material and activate system manually while wearing protective ensemble to suppress fire.

Respond to space craft hull breech alarm.

Respond to space craft toxic substance/outgassing alarm.

Respond to space craft CO2 alarm.

Respond to space craft general ECLS failure alarm.

Respond to space craft navigation alarm.

Respond to dental emergencies, following procedures and with equipment provided, during Cruise to Earth.

Conduct dental examination on crew member, manually/visually, to investigate complaint of tooth/jaw pain.

Interpret results of dental examination, cognitively with MCC consultation, to identify source of apparent tooth/jaw pain.

Prepare dental adhesive, fit, apply adhesive, and replace crown.

Administer pain medicine (Eugenol), manually as needed, to treat a crewmember's fractured tooth showing exposed pulp.

Apply direct pressure and hold until bleeding stops to treat loss of tooth of a crewmember.

Administer medication and if pain severe perform dental nerve block to treat crewmember's dental pain.

Apply temporary tooth filling and smooth excess (instruct patient to limit solid food consumption on affected side of mouth for 12-24 hours) to repair dental filling.

Perform medical diagnoses and evaluations, cognitively, during Cruise to Earth

Diagnose medical condition, cognitively and verbally through interviews with conscious ill or injured crewmember and physical exam.

Evaluate unresolved sleep disorder, cognitively per procedures, to diagnose problem and identify treatment/intervention.

Perform tests and examinations, physically, to support medical diagnoses during Cruise to Earth

Collect vitals from injured/ill crew (e.g. temp, pulse, oxygen saturation, respiration rate, blood pressure) with tools in kit, reassess as treatments/meds are administered.

Use medical software along with vitals/test results to help diagnosis condition of conscious or unconscious injured/ill crewmember.

Take image of the back of the eye, manually using a retinal camera (fundus exam), to test for visual impairment and/or increased intracranial pressure (VIIP).

Perform decompression sickness examination with the aid of an electronic form to determine if treatment is needed.

Collect Electrocardiogram (ECG) wave properties data with ECG hardware and leads placed on the patient for analysis of heart rate and variability.

Perform evaluation/treatment of chest pain by administering Aspirin, delivering oxygen with respiratory equipment, collecting vitals and ECG, and listening to lung sounds.

Check for capillary refill and pulses below injury location, apply splint, secure with ACE bandage to treat injured extremity (e.g., leg, arm).

Measure pulse and respiratory rate, administer oxygen and inhaled Albuterol, perform chest exam, and obtain blood pressure to treat difficulty breathing.

Obtain vital signs and photo-document rash, injury or other ailments to perform periodic health evaluation of a crewmember.

Test near and far visual acuity, visual field, contrast sensitivity, and potential cornea abrasions using a Panoptic tool to examine eyes.

Apply blood pressure device and monitor to assess patient's blood pressure.

Examine patient, manually/cognitively, to diagnose lower extremity stress fracture; proscribe reducing weight-bearing activities for up to 12 weeks.

Collect sample via swab and perform culture, manually, to test for bacterial infection.

Collect samples of blood/urine/saliva, manually, to prepare for lab tests.

Conduct lab tests (e.g., CBC, chemical panels, strep throat), manually on collected samples, to help diagnose medical problem.

Respond to medical emergencies, following procedures and with equipment provided, during Cruise to Earth.

Clear airway obstruction of choking crewmember by performing abdominal thrusts with fist below ribcage pulling sharply inward and upward until object clears.

Treat patient who becomes unconscious from choking by attempting to clear foreign object manually/pinch nose/apply breaths and begin CPR.

Perform CPR on unconscious /not breathing crewmember and determine if additional actions are needed as apart of Advanced Cardiac Life support.

Perform defibrillation on unconscious electrically isolated crewmember using AED to restore heartbeat.

Insert catheter in the bladder to drain urine (self-catheterize) for urine retention.

Administer traction and counter-traction until finger slips back in place to relocate a dislocated finger.

Administer traction and counter-traction until shoulder slips back in place to relocate a dislocated shoulder

Insert staples, sutures, or Derma bond depending on type and location of cut to repair skin laceration.

Insert catheter into pleural space between lung/chest wall, producing a pathway for air to escape to perform needle decompression of a pneumothorax (collapsed lung).

Insert an IV catheter and secure with medical tape to provide intravenous access for medications and fluids.
Attach prepared fluid set to an inserted IV catheter to administer IV fluids and medications.
Perform surgery, manually using available instruments, to repair a detached retina.
Perform surgery, manually using available instruments, to repair a compound fracture of arm or leg bone.
Perform surgery, manually using available instruments, to treat acute appendicitis.
Implement countermeasures (e.g., counseling, software) if symptoms of maladjustment or degraded behavioral health are detected among crew personnel.

Administer medications during Cruise to Earth.

Administer medications or an intramuscular shot (e.g. Epipen) to treat an allergic reaction.
Administer medication to suppress seizure/avoid loss of consciousness and uncontrolled muscle contractions.
Administer intramuscular shot, take vitals, and administer oxygen as needed to protect patient from injury from seizure.
Administer meds (e.g., antibiotics, antidiarrheal, antihistamine, decongestants, lubricants, pain relievers, sleep, steroids, stimulants and stool softeners) for conditions.
Administer hydrocodone and acetaminophen (Vicodin HP) and notify CMO to treat pain.
Administer Lidocaine or Epinephrine with a syringed needle, then create opening with scalpel to drain, to treat skin or dental abscess.
Apply a thin layer of Mupirocin (Bactroban) ointment and bandage affected areas to treat burned skin.
Deliver meds to lungs with inhaler by closing lips around the inhaler/inhaling slowly, holding breath for 10 seconds and removing inhaler from mouth and exhaling.
Apply medical drops into the ear canal to treat ear pain caused by blockage (i.e., Barotrauma) that is not alleviated by yawning or chewing.
Administer antibiotics, manually per instructions, to treat ear infection.
Administer antibiotic ointments/drops, manually per instructions, to treat eye irritations/abrasions/infections.
Administer appropriate antibiotic (oral or IV) to treat confirmed bacterial infection.
Administer epinephrine, oxygen, IV antihistamines and cortisone, and beta-agonist (e.g., Albuterol), manually, to treat anaphylaxis.
Administer sedative, manually via syringe, to treat crewmember experiencing a behavioral emergency.
Administer anti-inflammatory drugs, manually, to immobilized crewmember to treat spinal cord trauma.
Administer IV antibiotics, manually, to treat sepsis (administer vasopressor medication if blood pressure remains low).

Perform medical treatments during Cruise to Earth.

Irrigate eye and perform eye exam to treat chemical exposure to a crewmember's eye.
Minimize eye and skin exposure to toxics to prepare for treating exposed crewmate.
Remove exposed crewmates soiled clothes, particles/liquid and irrigate with water (flush eye with water) for respiratory exposure/follow Difficulty breathing procedure.
Place PHA QDM on crewmember/deliver oxygen for 2 hours, hydrate 1 liter per hour for 2 hours to treat decompression sickness.
Remove staples using a skin staple remover to complete repair.
Remove sutures with medical scissors to complete repair.
Insert Oral Airway device halfway into mouth and rotate 180 degrees before inserting until it is flush against the lips to aid ventilation of unconscious patient.
Place Ambu Bag mask over nose and mouth and gently squeeze bag to deliver breaths every 5 to 8 seconds to assist temporary ventilation of a compromised patient.
Deliver oxygen to a respiratory distressed patient by automated ventilation provided in a respiratory support pack.
Pinch fleshy part of nose, manually, for 10 minutes to stop nose bleeding.
Insert nasal packing and drops, manually per instructions, to stop persistent nose bleeding.
Remove wax from ear, manually using curette/medical drops, to treat ear pain.
Clean fingernail, apply antibiotic ointment, cover with adhesive bandage, manually until a new nail grows, to treat/protect fingernail damage from EVA.
Apply ice (multiple sessions) and administer pain medication as needed, manually, to treat back/shoulder/neck sprain/strain.

Apply ice/cold pack and compress with bandage, manually, to treat wrist, elbow, ankle, or knee sprain/strain.
Apply splint, manually, to treat unresolved wrist, elbow, ankle, or knee sprain/strain.
Drain sinus passageway (with nasal spray) and administer antibiotics, manually, to treat acute sinusitis.
Secure Airway, Breathing, Circulation (ABCs)/perform physiological monitoring (e.g., Vitals and Chem Labs), manually and cognitively, to manage acute radiation syndrome.
Apply physical force and binding/duct tape, manually with the help of another crew member, to restrain a crewmember experiencing a behavioral emergency.
Perform a reduction maneuver gently and slowly, manually with the assistance on another crewmember, to realign a dislocated elbow.
Secure crewmember to a flat surface, manually using restraints, to immobilize for treatment of suspected spinal cord trauma.
Apply cast, splint, or brace to extremity (e.g., arm, leg), manually, to immobilize simple fracture.

Perform administrative functions during Cruise to Earth.

Coordinate exercise device availability among crew to ensure access to maintain cardiovascular conditioning, muscle strength, and bone density.
Coordinate simulator availability among crew to ensure refresher training for all required skills and functions.
Coordinate crew response to meteor penetration, hull breech, fire, ECLS, or other emergency.
Monitor individual behavioral health by speaking with each crew member with the goal of identifying symptoms of maladjustment.
Schedule tasks and monitor performance of work to ensure that opportunities and resources are allocated appropriately among crew personnel.
Plan operations (e.g., EVA, maintenance of external components) using computer-based records in consultation with MCC and onboard personnel.

Conduct science and planning functions during Cruise to Earth.

Review expedition geology program objectives and procedures, using onboard resources, to prepare for reporting results.
Review expedition biology program objectives and procedures, using onboard resources, to prepare for reporting results.
Conduct astronomical observations, photography, and remote sensing to occupy cruise time with meaningful activity.
Conduct life science experiments to occupy cruise time with meaningful activity.
Conduct and record solar observations using onboard equipment and telescopes.
Conduct and record planetary and stellar observations using onboard equipment and telescopes.
Conduct and record radio astronomy observations using onboard equipment and telescopes.
Conduct and record Mars observations using onboard equipment and telescopes.
Conduct and record asteroid/comet observations using onboard equipment and telescopes.
Conduct and record Earth observations using onboard equipment and telescopes.

Conduct installation functions during Cruise to Earth.

Enter control inputs, manually, to configure space craft computer to support training simulation and task preparation.
Deploy supports/structures, manually, to configure dedicated area of space craft for medical procedure.
Modify pressure suit to adjust length of torso segment in response to spine elongation in zero gravity.
Enter control inputs, manually, to load software patch/reload software.
Program 3-D printer, manually via computer inputs, to fabricate a replacement part for a mechanical system onboard space craft.
Operate 3-D printer, manually via computer inputs, to fabricate a replacement part for a mechanical system onboard space craft.
Remove and trim object fabricated by 3-D printer, manually using hand tools, to prepare replacement part for a mechanical system onboard space craft.

Conduct maintenance functions during Cruise to Earth.

Review schematics and other documentation, visually, to isolate electronic fault in space craft.
Review schematics and other documentation, visually, to isolate plumbing (e.g., cooling, CLSS) fault in space craft.
Insert test equipment probes in electronic components, manually, and observe displays, visually, to isolate electronic fault in space craft.

Inspect circuit board, visually, to identify short circuit or loose/missing connection in space craft.
Inspect circuit board, visually, to identify scorching that might indicate degraded/faulty/failed electronic component in space craft.
Review documentation/enter control inputs, visually/manually, to diagnose software problem.
Inspect plumbing (e.g., cooling, CLSS), visually and with hand tools, to identify source of plumbing fault in space craft.
Remove and replace plumbing component (e.g., section, valve), using hand tools and schematics, to restore system functionality in space craft.
Retrieve spare parts/materials (e.g., valve, duct tape) from storage and move to work site in space craft, manually, to prepare for troubleshooting/repair.
Cut pipe, manually using hand saw, to remove damaged section of space craft plumbing.
Insert new section of pipe and attach in place, manually, using electric soldering tool, flux, and solder to repair space craft plumbing.
Remove 1 meter of duct tape from roll, manually, to temporarily repair leaking hose/fitting.
Wrap 1 meter of duct tape around hydraulic hose/fitting, manually, to temporarily repair leak.
Replace electronic connector on wire/cable, manually, using hand tools and spare parts.

Conduct navigation functions during Cruise to Earth.

Use sextant and star charts to estimate space craft position and course to compare to computerized navigation system.
Use sextant and star charts to estimate space craft position and course if computerized navigation system fails.
Convert results of manual navigation fix to propulsion changes necessary to achieve EOI, using tables and other calculation references.

Conduct piloting functions during Cruise to Earth.

Operate propulsion controls, manually, to maneuver space ship in preparation for ship-to-ship EVA.
Deploy and operate robot, remotely during cruise phase, to inspect external features of space craft.
Deploy and operate robot, remotely during cruise phase, to repair external features of space craft.

Monitor systems to ensure proper functioning during Cruise to Earth.

Monitor system displays, visually, to verify normal functioning of *life support system*.
Monitor system displays, visually, to verify normal functioning of *navigation system*.
Monitor system displays, visually, to verify normal functioning of *propulsion/attitude control syste*m.
Monitor system displays, visually, to verify normal functioning of *communication system*.
Monitor radiation-detection systems, visually/aurally, for evidence of Solar Proton and Galactic Cosmic Ray Events (SPE/GCR).
Monitor space craft atmosphere, visually/manually, by checking displays and comparing values to reference documents.

Adjust systems to ensure proper functioning during Cruise to Earth.

Adjust controls, manually per procedures, to maintain normal functioning of *life support system*.
Adjust controls, manually per procedures, to maintain normal functioning of *navigation system*.
Adjust controls, manually per procedures, to maintain normal functioning of *propulsion/attitude control system*.
Adjust propulsion/attitude control system controls, manually, to maintain proper course to Earth Orbit Injection (EOI).
Adjust controls, manually per procedures, to maintain normal functioning of *communication system*.
Adjust space craft atmosphere, manually, by making computer input commands in response to displays and reference documents.

Conduct refresher training to preserve skills during Cruise to Earth.

Review procedures for emergency mission abort (periodically during first third of cruise phase).
Review emergency procedures for various possibilities (fire, micro-meteorite impact, hull breech, outgassing, ECLS failure, etc.).
Conduct (training) simulation using space craft computer to refresh piloting skills for Earth Approach and Descent.
Conduct (training) simulation using space craft computer to refresh navigation skills for Earth Approach and Descent.

Conduct (training) simulation using space craft computer to refresh communication skills for Earth Approach and Descent.

Read procedures and technical information to prepare for conducting tasks during cruise, Earth Approach, and Descent.

PHASE 11: EARTH APPROACH

The eleventh phase of the mission begins approximately five days before landing with the crew transferring from the interplanetary ship into an attached Orion-type Earth Descent Vehicle (EDV) and undocking. The interplanetary spacecraft continues on it course unoccupied indefinitely while the crew makes final course corrections in cramped conditions onboard the EDV during the five-day approach to Earth.

Conduct communications checks/communicate observations/evaluations to other crew and MCC, verbally using comm system prior to and during Earth Approach.

Receive final course-correction information from MCC to prepare for entering Earth Descent Vehicle (EDV), undocking, and skip trajectory.

Communicate status of systems during checkout and undocking of EDV.

Communicate status of systems from EDV during Earth Approach.

Prepare for Earth Approach.

Don pressure suit, manually with the help of one other crew member, in preparation for entering Earth Descent Vehicle (EDV).

Open hatch, manually, to access EDV from (interplanetary) space craft.

Transfer cargo/personal/storage media items, manually, from interplanetary ship to Earth Descent Vehicle (EDV) to prepare for delivery to Earth surface.

Stow and secure all equipment, manually per load plan, to prepare EDV for Earth Approach and Earth Surface Descent.

Attach to individual crew maneuver position, while wearing pressure suit, in preparation for undocking the EDV from the interplanetary ship.

Monitor systems during Earth Approach.

Monitor automatic firing of retro rockets, visually, for undocking the EDV to achieve Earth Approach.

Monitor displays, visually, during undocking and maneuvering EDV away from interplanetary ship to prepare for Earth Approach and Descent.

Monitor displays, visually, during Earth Approach to prepare for Earth Surface Descent.

Monitor displays, visually using exterior video camera, to verify undocking of EDV.

Perform piloting functions during Earth Approach.

Enter control inputs to configure EDV computers in preparation for Earth Approach and Descent.

Enter control inputs, manually with gloved hand, to override automatic firing of maneuver thrusters if automated system fails.

Adjust thruster controls, manually with gloved hand, to undock EDV and maneuver away from interplanetary ship.

Adjust thruster controls, manually with gloved hand, to shut down EDV thrusters during Earth Approach.

Adjust attitude control thrusters, manually with gloved hand, to change course during Earth Approach.

Adjust attitude control thrusters, manually with gloved hand, to maneuver EDV to achieve correct skip trajectory.

Adjust controls, manually with gloved hand, to shut down attitude control thrusters and other systems in preparation for Earth Surface Descent.

Enter control inputs, manually with gloved hand, to activate thruster shut down if displays indicate failure of automated shut down.

Use EDV waste management systems for liquid/solid waste (i.e., toilet/bodily function) during Earth Approach.

Use EDV waste management system for liquid waste (i.e., toilet/bodily function).

Use EDV waste management system for solid waste (i.e., toilet/bodily function).

Prepare/eat meals during Earth Approach.

Remove food packages from storage, manually, to prepare meals during Earth Approach.

Remove drink packages from storage, manually, to prepare enable crew hydration during Earth Approach.

Distribute food and drink packages, manually, during Earth Approach.

Eat meal together with other members of the crew during Earth Approach.

PHASE 12: EARTH SURFACE DESCENT

The final phase of the mission begins with atmospheric entry, which will involve substantial g-loading and be similar to the "skip" trajectories of Apollo capsule landings. Precision will be required to avoid either intolerable atmospheric friction or skipping off the atmosphere. The duration from first atmospheric interface to landing under parachutes will be 20 to 30 minutes.

Conduct communications checks and communicate observations/evaluations to other crew and MCC personnel during Earth Surface Descent.

- Receive final thrust and duration information from MCC to prepare for Earth Surface Descent.
- Communicate status of systems to MCC, verbally, immediately prior to Earth Surface Descent.
- Communicate system status, verbally to crew members using internal communications equipment, during Earth Surface Descent.
- Communicate system status, verbally in heavy buffeting, to MCC using external communications equipment, during Earth Surface Descent.
- Communicate successful touch down, verbally and via text, to MCC using external communications equipment to confirm status.
- Communicate systems shut down and safing to crew via internal communication system to advise of status.
- Communicate systems shut down and safing to MCC via external communication systems to advise of status.

Prepare for Earth Surface Descent.

- Don pressure suit, manually with the help of one other crew member, in preparation for Earth Surface Descent.
- Stow and secure all equipment, manually per load plan, to prepare Earth Descent Vehicle (EDV) for Earth Surface Descent.
- Attach to individual crew maneuver position, while wearing pressure suit, in preparation for Earth Surface Descent.
- Assess crew members' physical and cognitive abilities, verbally using self-reports and established diagnostics, to determine capacities for Earth descent.
- Inspect Earth Descent Vehicle (EDV), visually, to verify that systems are go for descent maneuver.

Monitor systems during Earth Descent.

- Monitor automatic firing of Earth Descent Vehicle (EDV) retro rockets, visually, for Earth Surface Descent.
- Monitor displays, visually in heavy buffeting, during Earth Surface Descent.
- Monitor displays, visually, for parachute and retro rocket to verify correct functionality at appropriate times during Earth Surface Descent.
- Monitor displays, visually during buffeted descent, to assess proximity and verify touch down on Earth surface.
- Secure (other) flight systems, manually by control inputs, to ensure safing of EDV after touch down.
- Monitor displays, visually, to verify system functionality.

Adjust system controls, manually during buffeted descent, in response to displayed information.

- Enter control inputs, manually with gloved hand, to adjust Earth Descent Vehicle (EDV) temperature.
- Enter control inputs, manually with gloved hand, to adjust Earth Descent Vehicle (EDV) lighting.
- Enter control inputs, manually with gloved hand, to adjust Earth Descent Vehicle (EDV) ECLS.

Perform piloting functions during Earth Descent.

- Enter control inputs, manually with gloved hand, to configure Earth Descent Vehicle (EDV) computers, for Earth Surface Descent.
- Enter control inputs, manually with gloved hand, to adjust EDV pitch and yaw during Earth Surface Descent.
- Enter control inputs, manually with gloved hand, to maneuver Earth Descent Vehicle (EDV) during Earth Surface Descent.
- Enter control inputs, manually with gloved hand, to override automatic firing of retro rockets during Earth Surface Descent if automated system fails.
- Enter control inputs, manually with gloved hand, to adjust/override automatic systems in response to system displays, if necessary.
- Adjust retro rocket controls, manually with gloved hand during buffeted descent, to maneuver EDV to correct landing location, if necessary.
- Adjust controls, manually with gloved hand, to shut down retro rocket and other systems after touch down on Earth surface.
- Verify automated engine shut down by visually monitoring displays to ensure safing of Earth Descent Vehicle (EDV) after touch down.
- Enter control inputs, manually with gloved hand, to activate engine shut down if automated shut down fails, to ensure safing of Earth Descent Vehicle (EDV).

Verify automated landing system shut down by visually monitoring displays to ensure safing of Earth Descent Vehicle (EDV) after touch down.

Activate landing system shut down manually by control inputs if displays indicate failure of automated shut down, to ensure safing of EDV after touch down.

Perform post-Earth Descent functions.

Detach restraints and umbilicles from pressure suit, manually after landing, to prepare for egressing Earth Descent Vehicle (EDV).

Remove helmet, manually after landing, to prepare for egressing Earth Descent Vehicle (EDV).

Maneuver to hatch, manually while wearing pressure suit, to prepare for egressing Earth Descent Vehicle (EDV) after landing.

APPENDIX – LIST OF SOURCES USED TO DERIVE THE TASK LIST

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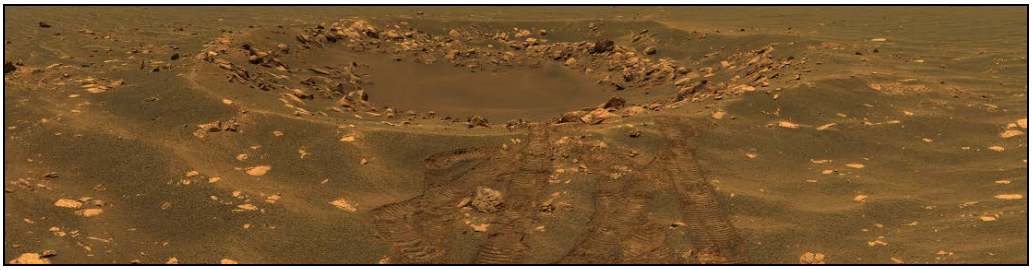

Credit: NASA/ASU/Cornell

Fram Crater on Mars, named for Fridtjof Nansen's ship.